AKENTEN APPIAH-MENKA UNIVERISTY OF SKILLS TRAINING AND ENTREPRENEURIAL DEVELOPMENT

MAMPONG- ASHANTI

INTEGRATED NUTRIENT MANAGEMENT ON GROWTH AND YIELD OF MAIZE (*Zea mays* L.)

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(MPHIL AGRONOMY)

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DECLARATION

STUDENT’S DECLARATION

I, Emmanuel Appiah declare that except for references to the works of other researchers which have been duly cited and acknowledged, this research is the result of my effort and that no part or whole has been presented for another degree elsewhere.

Signature………………………….

Date……………………………….

SUPERVISORS’ DECLARATION

We hereby declare that; this work has been supervised according to the guidelines for the supervision of a postgraduate thesis as laid down by the Akenten Appiah-Menka University of Skills Training and Entrepreneurial Development.

Prof. (Mrs.) Margaret Esi Essilfie (Principal Supervisor)

Signature………………………….

Date………………………………

Mr. Emmanuel Kwasi Asiedu (Co-Supervisor)

Signature………………………….

Date………………………………

DEDICATION

This research work is dedicated to Almighty God, my parents Mr. and Mrs. Appiah and my sister, Rita Appiah and Comfort Appiah (Naana).

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ABBREVIATIONS

kg	Kilogram
g	gram
m	meter
cm	centimeter
ha	Hectare
CM	Chicken manure
Omank.	Omankwa
Obatan.	Obatanpa
BC	Biochar
GB	*Gliricidia sepium* biochar
t/ha	Tonne per hectare
HSD	Honest Significant Difference
CV	Coefficient of variation
NPK	Nitrogen, Phosphorus and Potassium
OM	Organic matter
WHC	Water holding capacity
GPS	Global positioning system
CEC	Cation exchange capacity
EC	Electrical conductivity
NUE	Nitrogen use efficiency
MSD	Meteorological Service Department
AOAC	Association of Official Agricultural Chemists
IITA	International institute for Tropical Agriculture
EDTA	Ethylenediaminetetraacetic acid

ABSTRACT

Two field experiments were conducted at different locations of the research field at the Akenten Appiah-Menka University of Skills Training and Entrepreneurial Development (AAMUSTED), Mampong campus during the minor rainy season (August - December 2021) and the major rainy season (March - July 2022) to evaluate the effect of integrating biochar, chicken manure and NPK fertilizer on growth and yield of maize. The experiment was laid out in a 2 x 6 factorial arranged in Randomized Complete Block Design (RCBD) and replicated three times. There were six treatments [(T1 = 10 t/ha Chicken manure (CM), T2 = 300 kg/ha NPK 15:15:15, T3 = 2.5 t/ha *Gliricidia sepium* biochar (GB), T4 = 150 kg/ha NPK 15:15:15 + 1.25 t/ha GB, T5 = 1.25 t/ha GB + 5 t/ha CM) and T6 = No fertilizer (Control)] imposed on two maize varieties (*Omankwa and Obatanpa*). The results showed that amending soil with 10 t/ha CM or 1.25 t/ha GB + 5 t/ha CM improved soil chemical properties (total N, available P and increased soil pH and exchangeable bases). Omankwa x 10 t/ha CM or 1.25 t/ha GB + 5 t/ha CM interactions produced greater number of established plants which tasseled and silked earlier as compared to Obatanpa grown on the same amended soils. Obatanpa x 10 t/ha CM or 1.25 t/ha GB + 5 t/ha CM interactions produced significantly higher vegetative growth than Omankwa grown on 300 kg/ha NPK, 2.5 t/ha GB and 150 kg/ha NPK + 1.25 t/ha GB. Obatanpa x 10 t/ha CM or 1.25 t/ha GB + 5 t/ha CM interactions produced significantly higher grain yield, cob length, cob diameter and 100-seed weight per plot than Omankwa grown on the same treatments. It is recommended that farmers who practice organic agriculture should apply 10 t/ha CM or 1.25 t/ha GB + 5 t/ha CM to enhance early tasseling and silking of maize, vegetative growth and grain yield. Again, for the higher marginal rate of return, the application of 300 kg/ha NPK 15-15-15 is recommended although it did not produce a higher yield as compared to other amended plots.

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background of the Study

Maize (*Zea mays* L) is a monocotyledonous plant belonging to the genus *Zea* of the family *Poaceae* (Kabir *et al.*, 2019). Due to its versatility, it is widely grown in a variety of climates around the world (tropical, subtropical, and temperate zones) (Akinrinola & Fagbola, 2020).

Maize is ranked third in terms of global production and consumption behind wheat and rice, covering an estimated total area of 197 million hectares, with an annual global production exceeding 1 billion metric tonnes (Alam *et al.,* 2018; Erenstein *et al.,* 2022). Developing countries account for more than 90% of global production. Maize grows well in regions of marginal agricultural production. The crop has a short duration (3 – 4 months). Maize is the cheapest cereal grain available worldwide, however, it is a crucial component of the poor's diet (Rafii *et al.*, 2018). Maize is a key staple grain in Africa and Latin America. In Africa, more than 90% of maize production is utilized for food, with poorer areas consuming an average of 50 kg per person (Tanumihardjo *et al*., 2020). Africa utilizes 30% of the global supply of grain maize (Rafii *et al.,* 2018).

In many parts of Africa, including Ghana, the crop is grown for its essential properties. Maize is commonly eaten as an immature or matured entire kernel (i.e., boiled or roasted), freshly ground, or parched ground into grits and flour (Ekpa *et al.,* 2019). Between 26 – 58% of Ghanaians eat *kenkey* and other types of maize dumplings twice or more frequently each week (Haleegoah *et al.,* 2015). The maize grain contains B-complex vitamins, which are essential for human skin, hair, heart, and brain as well as aiding with digestion (Azawei & Alapuba, 2022). In the world, 30–40% of maize production is used for the manufacturing of food products for human consumption, and 60–70% of maize production is used commercially as animal feed (Castro-Muñoz *et al.,* 2019). Generally, maize is grown extensively throughout Ghana with commercial production occurring in the southern sectors. The main maize-producing areas in Ghana are the Bono, Ahafo, Eastern, and Ashanti regions, which produce 85 percent of the country's maize, with the remaining 15 percent grown in the northern sectors (Northern, Upper East, and Upper West regions) (Attipoe *et al.*, 2019). As a fast-growing cereal crop that can be grown in most regions of the country, yields of 4 to 6 tonnes per hectare have been estimated within four months.

1.2 Problem Statement

Food insecurity is a major challenge in Ghana. Maize is a major cereal crop cultivated in Ghana and serves as a source of food, nutrient, and income for most families. As a result, most farmers cultivate large acreages of maize across the country. In Ghana, maize is grown in every region, however, the yield of maize has steadily declined due to constraints of production which include low soil nutrient levels, and inappropriate agronomic practices, such as inadequate soil management practices to improve soil health (Itelima *et al.,* 2018). Additionally, continuous cropping on the same piece of land without external inputs to resupply removed nutrients, coupled with the already low soil fertility has depleted the soil of essential macro and micro nutrients needed for the proper growth and yield of maize crop (Tsado *et al.,* 2020). This has led to the yield averages of 1.5 t/ha below the achievable yield of between 5.4 - 6 t/ha in Ghana (Boullouz *et al.*, 2022), which has been reported to affect the attainment of Sustainable Development Goal 2, achieving global food security by 2030 (Cudjoe *et al.,* 2021). The relatively low soil fertility of the tropics and sub-tropics significantly hinders the sustainability of smallholder food production in sub-Saharan Africa (Raimi *et al.,* 2017).

Sub-Saharan Africa has experienced a progressive loss of soil nutrients as a result of the limited usage of both organic and mineral fertilizers (Moya *et al.*, 2019). Reduced use of conventional techniques for preserving soil fertility is a result of an increase in population that has caused a shortage of available land (Shah & Wu, 2019). Technologies based on the application of both organic and inorganic fertilizers simultaneously would result in a higher yield than either organic or inorganic fertilizers used separately (Mahmood *et al*., 2017). There is also limited knowledge and use of other organic sources such as biochar among most farmers. Biochar is regarded as a critical input for increasing and maintaining productivity while simultaneously minimizing pollution and over-reliance on fertilizers (You *et al.,* 2020).

Chemical fertilizers have been the conventional way of supplying nutrients to the crop. However, amending soils with chemical fertilizers is associated with high soil acidity, human health and environmental problems, as well as soil degradation as a means to increase crop yield in Ghana (Agbede, 2021). The exorbitant costs of inorganic fertilizers have rendered them unaffordable for the majority of resource-strapped small-scale farmers. Even though organic fertilizers alone enhance the soil's physical qualities, the nutrients are not fully absorbed and utilized by plants due to their slow release to crops which makes it difficult to supply crop nutrient demands during the growth period (Zhang *et al.,* 2020).

To effectively curb the negative impacts of synthetic and organic fertilizers on the soil properties and the environment, it is therefore, necessary to harness more appropriate, safer, and alternative solutions for sustainable crop production. This led to the treatment selection of two levels of biochar to be combined with synthetic and organic fertilizers in a factorial experiment to determine the effect of either organic, inorganic and biochar applied alone or in combination on maize during the minor and major rainy seasons in the transitional zone of Ghana.

1.3 Justification

Maize responds favourably to both organic and inorganic fertilizers. However, in the temperate and tropical zones of the world, using synthetic fertilizers is one of the most widely used methods of improving crop yield (Moji *et al.,* 2018) due to its ability to provide N, P, K, and Mg in balanced form. Due to their ability to improve macronutrient levels while retaining optimum soil physical and chemical qualities, synthetic fertilizers are widely used in maize cultivation. Synthetic fertilizers do not only increase crop yield by putting more nutrients in the soil for plant uptake, but they also have a positive impact on the soil's physicochemical and biological qualities (Zaman *et al.*, 2019). According to Zaki *et al.* (2020), nutrient uptake, growth, and yield of *Zea mays* were enhanced by the application of inorganic fertilizer since N, P and K fertilizers supplied all nutrients that are easily absorbed by the plants.

The application of organic manures to arable land is capable of improving the fertility status of the soil. Organic manure improves soil physicochemical and biological properties, such as soil structure and microbial abundance, as well as soil fertility and productivity (Akhtar *et al.*, 2018). Organic manure when added to the soils helps stabilize soil aggregate, root movement, and retention of water which encourages good root formation and plant growth (Soro *et al.*, 2015). Fageria (2012) attested to this by stating that soils with high organic matter content contain a greater abundance of water-stable aggregates and have a greater exchange capacity which translates into a better structure and water-holding capacity. The use of organic manure enhances higher growth, yield, and quality of crops. In a study on the effect of organic manure on the performance of maize, manure-treated soils recorded a significant increase in growth and yield components due to the continuous supply of nutrients (Eleduma *et al.*, 2020).

Farmers grow leguminous plants as fencing material around their farms. However, these leguminous plant wastes contain essential plant nutrients and can be recycled through biochar and used as amendments for maize production. Biochar is used as a soil conditioner because of its potential numerous benefits to agriculture and the environment, as well as its ability to improve the soil's physical and chemical properties *(*Jahromi *et al.*, 2018). A study on biochar-amended soils indicated that maize yield and yield components improved due to the increase in net water use efficiency and more moisture and nutrients available to the crop throughout the growing season (Danso *et al.*, 2019). Biochar enhances crop productivity of many cereal crops, which include maize. Peiris & Weerakkody (2015) found that growth and yield increased significantly in maize plants that received biochar. Biochar amendment improves the poor cation exchange capacity (CEC) of acidic soils by increasing the negative charge on soil minerals (Hale *et al.*, 2020). Furthermore, biochar is negatively charged (6–59 cmolc/kg) (Munera-Echeverri *et al.*, 2018), and its addition to soil increases soil CEC. The increased CEC generated by the addition of biochar to tropical soils has been hypothesized to improve NH_4+ adsorption and, as a result, reduce N leaching (Borchard *et al.*, 2014). The goal of this study was to discover a low-cost, locally derived method that can help balance crop nutrition, increase nutrient availability, and serve as a liming material to control soil acidity in the production of maize.

1.4 Objectives of the Study

1.4.1 Main Objective

The main objective of the study was to determine the effect of integrating biochar, organic and inorganic fertilizers, and applying either alone or in combination on the growth and yield of maize (*Zea mays*).

1.4.2 Specific objectives

The specific objectives were to:

1. Assess the effect of *Gliricidia sepium* biochar, chicken manure, and inorganic fertilizer (NPK 15:15:15) on soil physicochemical properties.
2. Compare the effectiveness of *Gliricidia sepium* biochar, chicken manure, and inorganic fertilizer (NPK 15:15:15) on the growth of two maize varieties.
3. Evaluate the effect of *Gliricidia sepium* biochar, chicken manure and NPK (15:15:15) applied either alone or in combination on the yield of two maize varieties.
4. Ascertain partial-benefit analysis and recommend to farmers the nutrient practices that would be most profitable for maize production.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Origin and Distribution of Maize

The world's most widely grown crop is maize (Liu *et al.*, 2016). Maize's origin is disputed, with scientists, historians, and archaeologists suggesting opposing views (Hufford *et al.*, 2012). The majority of scientists assume that maize originated in southern Mexico and was domesticated by indigenous peoples around 10,000 years ago (Kistler *et al.*, 2018). The modern maize crop originated from Balsas teosinte (*Zea mays parviglumis*), a wild grass.

In the 16th century, Christopher Columbus and other explorers and colonizers brought maize seeds from Cuba to Spain, which was later spread to Italy and other parts of the world (Mir *et al.*, 2013). Maize was brought to Africa by Spanish and Portuguese traders from Mesoamerica in the 16th century, and due to its great productivity and multiple uses, the crop quickly spread over the continent (Aci *et al.*, 2018), and is now the most important cereal crop widely cultivated in sub-Saharan Africa (SSA) (Abate *et al.*, 2017). The crop can also be cultivated in a wide range of environments, including soil type, soil fertility, moisture level, temperature, and cultural practices (Mafouasson *et al.*, 2018).

2.2 Taxonomy and Morphological Description of Maize

Maize (*Zea mays* L) belongs to the genus *Zea* of the family *Poaceae*. It is an annual grass with a gritty texture. The plant has a delicate, densely branching root structure. A mature maize plant's root system spans 1.5 meters laterally and 2 meters or more downwards. Maize plants typically have three types of roots: i) seminal roots - those that emerge from radicals and last for a long time, ii) adventitious roots are fibrous roots that grow from the lower nodes of the stem below ground level and are the plant's active and effective roots. and iii) brace or prop roots, produced by the lower two nodes (Bhupender *et al.,* 2012). The prop roots emerge from the nodes above ground and aid in firmly anchoring the plant (Macauley & Ramadjita, 2015).

The maize stem typically grows to be 3 to 4 cm thick. Depending on the variety, maize stems range in height from less than 0.6 m to more than 5.0 m. The stem is a solid, cylindrical structure with nodes and internodes. The maize stalk is herbaceous and segmented into internodes, the stalk has 8-12 internodes, and each node has a leaf. The number of internodes varies between 6 and 20. The height of the stalk varies between 1.0 and 3.5 m.

According to Macauley & Ramadjita (2015), the number of leaves varies between 8 and 16. A leaf can range in length from 80 to 150 cm and width from 9 to 10 cm. According to Zhang *et al.* (2015), large, narrow, opposite leaves emerge from the nodes, and they alternate on opposite sides of the stem. A strong mid-rib runs the length of the leaf, and stomata are arranged in rows across the entire leaf surface.

Male and female flowers are borne on the same plant as different inflorescences on the maize plant. Male flowers appear in the tassel, while female flowers bloom on an ear-shaped receptacle that emerges from the leaf axils towards the stem's midpoint. Typically, 1-3 or more of these ears emerge (Gebre & Yoseph, 2014). Pollen from the terminal tassels is shed, and strands of "silk," or flower stigmas, emerge from the terminals of the ears and husks. Pollen is blown by the wind and comes into contact with the silk or stigma that has developed. The male gamete fertilizes the egg, which develops into a corn seed/kernel.

2.3 Nutritive Value and Uses of Maize

The maize crop is utilized both for nourishment and feed purposes all over the world (Asif *et al.,* 2020). Maize is a good source of protein and vital minerals including magnesium and phosphorus, which help to alleviate vitamin A deficiency and protein-energy malnutrition around the world (Kumar & Jhariya, 2013). Chemically, maize kernel constitutes around 72 to 75% carbohydrate, 7 to 11% protein, 10.5% moisture, 4% lipid, 2% fiber, and 1.2% ash and has an energy density of 365 kcal/100g (Saeed *et al.*, 2021).

Maize also contains vitamins A, C, and K, as well as a substantial amount of beta carotene and a moderate amount of selenium, all of which support the thyroid glands and immune system's good functioning (Azawei & Alapuba, 2022). Maize is prepared and eaten in Ghana as ‘banku’, ‘apkle’, and porridge (Essilfie *et al.*, 2017). The starchy component of the kernel is utilized in foods as well as a variety of other items like adhesives, textiles, pharmaceutical tablets, and paper manufacturing (Ovharhe *et al.*, 2021).

2.4 Varieties of Maize

Researchers from various ecological locations provide distinct sorts of maize cultivars, resulting in a diverse range of maize cultivars. In Ghana, maize is divided into two cultivars based on pollination mode: open-pollinated varieties (OPV) and hybrids. The Ghana Grain Development Program, GGDP, created the majority of these OPVs, including *Omankwa, Aburohema, Abontem, Golden Crystal, Obatanpa*, and others (Tetteh *et al.,* 2018). Scientists from the Council for Scientific and Industrial Research-Savanna Agriculture Research Institute (CSIR – SARI), Nyankpala, and the CSIR-Crops Research Institute (CRI), Kumasi in Ghana produced the *Mamaba, Dadaba, Cida-ba, CSIR-Etubi*, and *CSIR-Enii-Pibi* hybrid cultivars.

Quality protein maize (QPM) and normal maize are two further classes. QPM breeding began with the goal of enhancing the nutritional value of maize grain protein. Normal maize grain is used as part of a diverse diet - which is out of range for the vast majority of people in underdeveloped countries (Mamatha *et al.,* 2017). Furthermore, scientists from the Council for Scientific and Industrial Research (CSIR) - Crops Research Institute (CRI), Kumasi in Ghana have developed maize cultivars that can provide balanced nutrition for human consumption. *Obatanpa, Dobidi, Aburotia, Okomasa, Abeleehi, Golden Jubilee, Abontem, and Mamaba* are some of the most common maize types in Ghana.

2.5 Growth Requirements of Maize

2.5.1 Climatic Requirements

Maize is a very significant crop all around the world. According to Mulungu & Ng'ombe (2019), maize can adapt to a variety of environmental conditions and is widely cultivated from the tropics to the temperate zones between latitudes of 50˚ north to about 45˚ south.

Maize requires a constant supply of water and suffers greatly during droughts. Yin *et al.* (2014) asserted that during the growth period, maize needs 200 to 450 mm of rainfall. Durodola & Mourad (2020) further indicated that maize grows best in areas with a yearly rainfall of 600 -1000 mm. Maize is sensitive to both drought and flooding. Drought during the first four weeks of flowering (silking and tasseling) can result in significant yield losses; however, the drought that occurs from the mid to late vegetative stage onwards has little effect on tassel anthesis but delays the ear silking process (Bhupender *et al.,* 2012). Maize has two periods in its vegetative growth stage when inadequate moisture availability can disastrously affect yield. The first is during establishment when the stand can be substantially reduced because of the inability of seeds to imbibe water against the gradient of soil water potential. Song *et al.* (2019) discovered that severe water stress at the seedling stage had a more significant influence on maize growth and development than stress imposed during the other stages.

Maize thrives and does well in a warm climate with adequate moisture. Maize is not grown in areas where the mean daily temperature is less than 19 ºC. It is a warm-season crop and the optimal temperature requirement is 11 – 32 °C during the day and around 14 °C during the night with 5 to 6 hours of sunshine per day for good growth (Wang *et al.*, 2018), however, the maximum plant yield is obtained at temperatures of 21-30 ºC. Temperature strongly influences the development of maize. Soil temperature of 26 °C to 30 °C is optimum for both germination and seedling growth, however, the minimum temperature for germination is 18-21 °C (Paul & Oluwasina, 2011). Dahal *et al.* (2021) also argued that the minimum temperature required for maize seed germination is 10 °C and the optimum temperature for tasseling and silking is 20 - 30 °C.

2.5.2 Soil Requirements

Maize requires nutrient-rich and moist soil with a pH ranging between 5.8 to 7.0 for its cultivation (Wang *et al.*, 2018). Maize grows well in a wide range of soils, but for greater yields, it requires deep, medium-textured, well-drained, rich soils with a high water holding capacity and a pH range of 5.5–8.0 (Durodola & Mourad, 2020). Adzemi *et al.* (2017) stated that the most ideal soil for maize crops is silty loam or loam topsoil and also fair brown silty clay loam with fairly sandy soil which has a pH of 6 to 7.5. Maize does not like water-logged or shallow soil. Maize normally does very well on moist soils and badly on pure clayey or sandy soils. Maize is not tolerant to saline soils or irrigation with saline water, however, it was reported by Wang *et al.* (2015) that irrigation with saline water will reduce maize yield by not more than 10% compared with freshwater irrigation, but long-term saline water irrigation will result in significant yield losses, even for low concentrations of salt.

Maize is reasonably tolerant to soil acidity, but if the soil is very acidic, liming will improve the soil and enhance maize yields. Maize plants, particularly at the seedling stage, are susceptible to salinity; salinity is major stress responsible for the inhibition of seed germination, delay in germination time in crops, and subsequent seedling establishment (Buckner *et al.,* 2016). Soil salinity influences the uptake of nutrients but decreases dry matter production probably most often due to decreased soil water and increased toxicity of sulfate in the soil solution (Rani *et al.,* 2019). Adu *et al.* (2014) also stated that high yields are obtained from maize planted on deep, fine-structured, well-aerated, well-drained loamy soils that are rich in organic matter.

2.6 Production Estimate of Maize

Maize cultivation in Ghana has been ongoing for centuries. After its introduction in the late 16th century, it got established as an essential staple crop in the southern part of Ghana. Maize is the most widely produced and consumed cereal crop in Ghana and its production has seen an increasing trend at a rate of about 4.17 percent per annum (Dowswell *et al*., 2019). In 2018, maize yields averaged 2.3 metric tonnes (mt). In 2020, maize yield was estimated to increase to 3.1 metric tonnes (mt) in Ghana (FAOSTAT, 2021).

Globally, about a billion tonnes of maize are produced per year. FAOSTAT (2021) reported that, on a worldwide scale, 1137 million metric tonnes of maize were produced during (2017-2019) and 1.05 million thousand tonnes in 2020. The top ten maize-producing countries for 2021 (metric tonnes) include United States (383,943), China (272,552), Brazil (116,000), EU-27 (70, 499), Argentina (53,000), Ukraine (41,900), India (32,500), Mexico (27,600), South Africa (16,300), and Russsian Federation (15,225) (FAOSTAT, 2021). The top eleven maize-producing countries in Africa for 2021 (metric tonnes) include South Africa (17,000), Nigeria (11,600), Ethiopia (9,000), Tanzania (6,500), Egypt (6,400), Malawi (4,200), Zambia (3,620), Mali (3,500), Kenya (3,500), Uganda (2,800), and Ghana (2,760) (FAOSTAT, 2021).

2.7 Planting of Maize

Maize is cultivated by seed and is grown twice a year in the Southern sector of Ghana. The first season is from April to July (major rainy and cropping season) while the second season runs from September to December (minor rainy and cropping season). The recommended planting time for maize in the major rainy season is mid-March to the end of April and mid-July to early September for the minor rainy season (Adu *et al.*, 2014). There is only one rainy season in Ghana's northern region. Delaying the maize sowing date can diminish grain yields through reduction in the number, size, and/or reduction in the assimilate supply to grains during the grain filling period (Bonelli *et al.,* 2016).

Early planting is associated with higher yields when rainfall is normal. The most suitable sowing time for maize is determined based on the soil moisture content before the end of April, however, planting maize early is important for the crop to utilize the entire growing season and consequently maximize yield (Lu *et al.*, 2017). When planted as a single crop, it can be sown at 80-90 cm between rows and 40-60 cm within rows, with two plants per hill, for a stand population of 37,000 - 62,500 plants per hectare, the optimum planting density is adjusted according to the local conditions and types of varieties to be grown. If early-maturing varieties are to be planted, 75 cm between rows and 40 cm between stands are to be used, however, for intermediate to late-maturing varieties, 80 cm between rows and 40 cm between stands are recommended (Adu *et al.*, 2014).

2.8 Agronomic Practices of Maize

2.8.1 Weed Control

Maize is most susceptible to weed competition, however, weeds are more injurious to crop growth and yield in the early phases of development (Berdjour *et al.*, 2020). Korav *et al*. (2018) stated that weeds have a competitive advantage over young seedlings and therefore it is necessary to keep fields free from weeds at least in the first 4-6 weeks after sowing. Significant yield losses of approximately 10% occur if weeds are not controlled in maize during the first 8 weeks after sowing (Martin *et al.,* 2015).

Weeding can be carried out entirely manually or may be partially or fully mechanized. Alternatively, herbicides can also be used to control weeds. Chemical weed control is preferred because its mode of action is fast and easy, there is no mechanical damage to the crop, and is less cost-effective (Strike & Vance, 2017). Glyphosate, Paraquat, and Atrazine are some herbicides that are recommended for use in controlling weeds in maize farms. Preventive measures such as the use of clean seed and manures and cultural practices such as time and method of sowing, crop density and geometry, crop varieties and crop rotation are also used in controlling weeds in maize farms (Mohammadi, 2013).

2.8.2 Pest and Diseases and their control

Throughout its range, maize is prey to more than 90 species of herbivorous insects (Meihls *et al., 2*012). Maize is prone to several pests and disease attacks in the field, at harvest, and during storage. More than 40 species of insect pests have been recorded to attack maize in the field and storage which has been reported to cause significant loss to maize when not treated (Assefa & Ayalew, 2019). Major pests and diseases of maize include fall armyworms, stem borers, grasshoppers, weevils, maize streak, smuts, rust, and bacterial blight respectively. The usage of resistant varieties, crop rotation, early planting have been proposed to control pests and diseases of maize (Abrahams *et al.,* 2017).

2.9 Uses of Leguminous trees as biochar

Leguminous trees are fast-growing, nitrogen-fixing shrub that tolerates regular removal of coppice for use as green manure or mulch for crops (Mukangango, 2019). The leguminous green manure has a rapid turnover rate that enables it to release N quickly while still sustaining the soil's organic C content, enhancing crop development and yield (Chen *et al.,* 2014).

According to research, leguminous plant prunings can be used to produce biochar. Leguminous prunings are converted into biochar, which makes it simpler to use as a soil supplement and can be utilized as an alternative to preserve or increase soil organic C reserves. Jahromi *et al.* (2018) asserted that the altered biochar acts as a stable soil organic amendment that may store soil water for crop use and resist microbial degradation. Numerous studies have shown that applying biochar can enhance soil C stores, soil fertility, and crop yields (Kätterer *et al.,* 2019). *Leucaena leucocephala* biochar addition at 30 t/ha only had a substantial yield of *Amaranthus* when applied on very strongly acidic soils (Elias *et al.,* 2020). This agrees with many previous studies that have shown the potential for biochar to increase crop yields on most acidic and tropical soils (Jeffery *et al.,* 2017).

2.10 Effect of Inorganic Fertilizers (NPK 15:15:15) on Soil Physico-Chemical Properties

Maize has a high requirement for nutrients, particularly nitrogen, phosphate, and potassium. Due to the comparatively huge amounts of nitrogen, potassium, and phosphorus that plants can absorb from the soil, these three nutrients are referred to as primary macronutrients (Amare, 2020). About 95% of cereal crops are cultivated on intensively cropped fields, and crop residues are inadequate to replenish the nutrients depleted yearly (Bisen & Rahangdale, 2017). As a result, a balanced supply of essential elements can increase crop productivity. Inorganic or organic fertilizers can be used as elemental sources. Because maize is a heavy feeder in terms of extracting nutrients from the soil, it needs and responds well to supplementary fertilizers (Ten-Berge *et al.,* 2019).

Synthetic fertilizers are widely used in agriculture because of their ability to improve macro and micronutrient levels, resulting in optimal crop growth and yield. Synthetic fertilizers (NPK) are essential for improving the fertility of soil and crop yield (Bhatti *et al*., 2017). Synthetic fertilizers are compounds containing high concentrations of nutrients necessary for plant growth and development (Pahalvi *et al.,* 2021). Asante *et al.* (2020) reported that synthetic fertilizers are made to supply micronutrients found in trace amounts in specific soils and can also provide significant amounts of nitrogen, phosphorus, and potassium available to crops.

Due to their ability to improve macronutrient levels while retaining optimum soil physical and chemical qualities, inorganic fertilizers are widely used in maize cultivation. However, Zaman *et al.* (2019) reported that chemical fertilizers not only increase crop yield by putting more nutrients in the soil for plant uptake, but they also have a positive impact on the soil's physical, chemical, and biological qualities. In acid soils and nutrient-depleted soils, the application of N, P, and K fertilizers resulted in pH changes of 5.1 to 5.3 and 6.2 to 5.8, respectively (Adeniyan *et al.,* 2011).

2.10.1 Effect of Nitrogen on Growth and Yield of Maize

Nitrogen is the most essential element in the nutrition of compositing microflora since it is required for the simulation of carbon substrate in organic waste. In many production systems, nitrogen is one of the essential elements that limit cereal crop development and yield potential (Zhou *et al.,* 2017). Nitrogen is an important nutrient for maize and a key determinant of crop yield, primarily through its impact on photosynthesis and other biological activities such as water and mineral absorption, vacuole storage, and xylem transport (Aziiba *et al.,* 2019).

Mekdad (2015) observed an increase in maize yield as a result of increased nitrogen fertilizer levels and split application. It could be due to nitrogen's importance as a macronutrient for plant nutrition, as well as its significance in stimulating vegetative development by enhancing leaf initiation and increasing chlorophyll content in leaves, which could improve the photosynthetic process. Studies on the timing of nitrogen application on clay loam soil in central Ethiopia discovered that adding half of the total nitrogen dose at the mid-vegetative stage and the rest at the full tasseling stage increased grain yield and protein content of crops significantly (Niaz *et al.,* 2015). According to Hammad *et al.* (2011), N fertilizer application had a significantly greater impact on maize grain productivity; this could be because N fertilizer application increased plant uptake of other elements. This can be explained by the fact that increased N availability promoted the proliferation of small roots and root hairs, which improved the absorption capacity per unit of dry weight.

Sharifi & Namvar (2016) showed that N deficiency in maize during vegetative growth can induce early maturity and consequently reduce the kernel-filling period. Excess nitrogen causes leathery dark green succulent leaves or crops, which delays maturity, reduces product quality, and increases disease and lodging susceptibility (Das & Avasthe, 2018).

2.10.2 Effect of Phosphorus on Growth and Yield of Maize

Phosphorus is the second most essential macronutrient after nitrogen as a mineral nutrient in terms of the normal growth and development of plants and most commonly limiting agricultural production in most parts of the world (Meng *et al.*, 2021). Many components of crop physiology, including photosynthesis, blooming, seed formation, plant respiration, cell division, energy storage, and early crop maturity, are enhanced by an appropriate supply of P (Jeo*ng et al.*, 2017).

Phosphorus increases starch synthesis, however, unlike nitrogen, it accelerates rather than slows down the maturation process. Bashir *et al.* (2015) concluded from their research that applying P to wheat at a rate of 100 kg/ha has a significant impact on wheat yield. Bashir *et al.* (2015) further reported an increase in biological yield, plant height, tiller number, P efficiency, and harvest index. According to Javid *et al.* (2015), the use of P via fertigation increased maize grain yield and its components significantly when compared to the control. However, fertigation was a more efficient form of P application and the finest alternative for producing maximum maize growth and grain yield. Abdullahi *et al.* (2020) observed that 30 kg/ha of P fertilizer should be applied to maize for optimal development and yield. These findings corroborate research by Rashid & Iqbal (2012), who discovered that P application improved maize fodder yield and quality.

In Ghana, Naabe *et al.* (2021) studied the yield response and economic benefits of groundnut to phosphorus fertilization and inoculant rates, it was discovered that 60 kg/ha P_2O_5 produced the highest grain yield of 2708.3 kg/ha. According to Adjei-Nsiah *et al.* (2018), P-fertilizer application increased yields by 296; 527; and 390 kg/ha for cowpea, peanut, and soybean grains, respectively, in their research on three different crops. According to Nkaa *et al*. (2014), P fertilizer significantly improved the growth and yield qualities of cowpea; however, P improved the seed yield, the weight of 50-seeds, the number of nodules and the weight of nodules in all varieties studied.

Plants deficient in phosphorus have a shortened root system, and dark green or reddish-purple leaves, especially at the leaf tips in the young plant, and flowering and ripening are delayed (Mahlo, 2020). Furthermore, ears are small, twisted, and have underdeveloped kernels, resulting in a lower grain yield.

2.10.3 Effect of Potassium on Growth and Yield of Maize

Potassium (K) is the third macronutrient essential to plant growth. In soil, however, K is needed in large amounts by many crops because it is essential for maintaining the osmotic potential and rigidity of the cells of plants. K, therefore, plays a vital role in water relations in plant water uptake and also improves the productivity of a variety of cereal crops, including maize (Ali *et al.*, 2020). According to Hasanuzzaman *et al.* (2018), K is important for photosynthesis, osmotic pressure regulation, stomatal movement, protein synthesis, and cation-anion balance in the soil, and promotes crop tolerance to stress, lodging, disease, and drought. It also aids crop quality and yield.

Hussain *et al.* (2015) investigated the impact of potassium fertilization on maize crop nutrient uptake, growth, and physiology and discovered that increasing the potassium application rate significantly enhanced nutrient uptake, plant development, as well as respiration rate, net photosynthesis and sub-stomatal CO_2 concentration. Khan *et al.* (2015) studied the effect of potassium levels on four maize hybrids, K levels of 90 kg/ha improved maize yields and yield-related components, whereas levels of potassium over 90 kg/ha had little effect. Iqbal & Amanullah (2015) also indicated that applying 90 kg/ha K produced more leaves per plant, optimum average leaf area, accumulated more dry matter and had a higher biological yield and harvest index of maize than the untreated plots.

According to Ul-Allah *et al.* (2020), potassium plays a crucial role in a variety of plant metabolic processes and when it is adequately available, it maintains plants' health even under drought stress which increases yield and water productivity. A study conducted by Amanullah *et al.* (2016) on Potassium management for improving growth and grain yield of maize (*Zea mays* L.) under moisture stress conditions indicated that foliar and soil potassium applications increased maize performance under moisture stress.

Potassium deficiency in maize includes poor root system, reduced stalk strength in corn, resulting in lodging problems, and reduced disease resistance leading to yield reductions (Das & Avasthe, 2018).

2.11 Effect of Poultry Manure on Soil Physico-Chemical Properties

Chicken litter and chicken manure are by far the most prevalent waste products from the poultry industry, as well as the most popular source of organic manure used to improve soil properties (Tańczuk *et al.*, 2019). According to Aziz *et al.* (2020), fresh chicken manure contains 0.9-1.5% nitrogen, 0.4-0.5% phosphorus, and 0.8 – 1.7% potassium.

According to Ahmad *et al.* (2016), the physical and chemical composition of poultry manure is influenced by the bird type, feed intake, water consumption, number of birds per unit area, type and amount of litter, time of application, manure storage, and management. Similarly, Essilfie (2015) reported that environmental factors during litter production and preservation have an impact on poultry manure quality.

Poultry litter is rich in nutrients, including trace and non-trace elements, and its use can improve soil productivity and quality by enhancing aggregate formation and stability (Jaja *et al.*, 2022). Studies have indicated that applying poultry manure can increase soil fertility in terms of K and P without increasing soil salinity in sandy soil and continuously lowering soil temperature by 2-2.3 ^{o}C (Wali *et al.*, 2020). Yolanda *et al.* (2014) reported that poultry manure contains organic matter that enhances soil water holding capacity, improves soil structure, soil aeration, and water permeability, functions as a pH buffer, and contains metal-organic matter compounds that help make micronutrients available to crops. Indira & Annadurai (2016) further reported that application of poultry manure increases soil microbial activity and helps to improve both the physical and chemical qualities of the soil.

Soremi *et al.* (2017) found that applying poultry manure increased organic carbon, exchangeable bases, and effective cation exchange capacity in soils, as well as concentrations of N, P, and K in plant tissue. In comparison to NPK-treated soils, Atijegbe *et al.* (2014) discovered that the addition of 10 t/ha of poultry manure enhanced the physicochemical parameters of the soil, lowered soil bulk density and temperature, and increased porosity and moisture content. These findings agree with the work by Deryqe *et al.* (2016) who reported that applying chicken manure at rates of 5, 10, and 15 Mg/ha improved soil organic matter by 0.44, 0.96, and 1.68 percentage points, respectively.

2.12 Effect of Poultry Manure on Growth and Yield of Maize

Chicken manure has been used worldwide for crop improvement and yield. According to Jaja *et al.* (2022), chicken litter is an important source of organic fertilizer that is normally surface-applied on fields for the improvement of soil quality and increased yield in agricultural production.

Asfaw (2020), in his study of the impact of some animal manures on the growth and yield of maize, observed that the use of poultry manure at the rate of 20 t/ha is a valuable alternative to chemical fertilizer for growth and yield of maize plants; however, its impact on yield depends on soil types, tillage, method of application, and cropping system. Similarly, Essilfie *et al.* (2017) asserted that the application of 3 t/ha CM enhanced maize grain weight, cob length, and cob diameter respectively. Kareem *et al.* (2018) further reported that the application of 2.5 t/ha poultry manure for the production of maize resulted in higher grain yield and better biomass production.

Kareem *et al.* (2017) also observed a significant increase in the number of leaves, leaf area, plant height, and stem girth of maize when 5 t/ha poultry manure was applied at the time of sowing. Soro *et al.* (2015) also observed a significant increase in the yield of maize as enhanced by the application of six days wind stored poultry manure applied at the rate of 7 t/ha. Aziz *et al.* (2020) further asserted that application of 4 t/ha CM significantly increased the number of leaves of forage sorghum than the control.

Adekiya *et al.* (2020) in their study of different organic manure sources and NPK fertilizer on okra revealed that amongst various organic manures, poultry manure produced significantly higher plant growth, yield, mineral, and proximate composition of okra because of its high soil chemical properties which could be related to its lowest C: N ratio, lignin, and lignin: N ratio. Similarly, Fagwalawa & Yahaya (2016) studied the effects of sheep, cow, and poultry manures and their combinations on the growth and yield of okra, their result also discovered that poultry manure had the highest yield.

2.13 Effect of Combined use of Organic and Inorganic Fertilizers on Soil Physico-Chemical Properties

The integrated use of organic and synthetic fertilizers as a soil nutrient management technique has been proven to be a sound fertility management approach for long-term agricultural productivity than sole application of chemical fertilizer. Yang *et al.* (2020) found that combining organic and inorganic fertilizers increases soil organic matter and total nitrogen content while also enhancing the soil microclimate in wheat/maize crops.

According to Xiao *et al.* (2017), synthetic fertilizer alone deteriorated soil quality and acidified the soil, but organic fertilizer in combination with inorganic compound fertilizer improved soil quality. Han *et al.* (2016) found that integrating organic and inorganic synthetic fertilizers improves soil productivity and fertility while reducing the damage caused by synthetic fertilizers. Similarly, Bhatt *et al.* (2019) reported that using animal manure in combination with inorganic fertilizer improves soil fertility and crop yield. Han *et al.* (2016) reported that using NPK in combination with organic wastes improved the soil's pH, EC, organic carbon, and decreased bulk density.

Agbede *et al.* (2017) reported that chemical fertilizers are the primary cause of soil acidity, nutrient loss, nutritional imbalance, and deterioration of soil physical characteristics and organic matter status. However, Brar *et al.* (2015) found that mixing inorganic and organic fertilizers (100 percent NPK + FYM) increased soil chemical parameters like CEC and pH, resulting in greater maize and wheat yields. According to Han *et al.* (2016), soil acidification is caused by the sole application of NPK fertilizer, whereas organic manure + NPK fertilizer treatments significantly improved soil pH.

According to Mahmood *et al.* (2017), the use of both inorganic and organic fertilizers significantly increased soil organic C content, total nitrogen, and accessible soil nutrients, as well as improved overall soil characteristics. Redda & Kebede (2017) researched the effects of the integrated use of organic and inorganic fertilizers on soil properties performance, using rice. The results showed that the integrated use of organic manure with inorganic fertilizers not only increased the rice yield but also improved the fertility status of the soil than inorganic fertilizers alone. Similarly, Essilfie (2015) indicated that the combined application of chicken manure and inorganic fertilizer is a better option for effective soil fertility management than either chicken manure or inorganic mineral alone.

Ding *et al.* (2017) reported that manure application increases fungal diversity in the soil and when applied with inorganic fertilizers, reverses the declining microbial biodiversity trend associated with inorganic nutrients applied alone. Faisal *et al*. (2017) reported that the growth and yield of maize were substantially improved by fertilizer application alongside organic manures whereas soil total organic C and total N, P, and K contents increased when inorganic fertilizers were combined with organic manures. Further, the C: N ratio, soil organic carbon, and total N, P, and K increased while soil pH and soil bulk density were decreased with the integrated application of organic manures with chemical fertilizer. Iqbal & Sapsal (2019) further reported that the combined application of organic and inorganic fertilizers can significantly improve the physical and chemical properties of the soil (CEC, exchangeable calcium, and availability of N, P, K, and Zn, and Fe.).

2.14 Effect of Combined use of Organic and Inorganic Fertilizers on Crop Performance

Due to the rising cost of synthetic fertilizers and the bulkiness and scarcity of organic manure, nutrient combination to promote and maintain crop growth is essential. In several countries across the world, combining organic manures and synthetic fertilizers is a sound soil fertility management strategy (Biramo, 2018). A combination of organic and synthetic fertilizer nutrient sources has the potential to improve crop growth and yield through appropriate nutrient uptake by the crop.

According to Wirayuda & Koesriharti (2020), applying 10 t/ha goat manure and 250 kg/ha NPK fertilizer has a significant impact on corn development and yields. Several studies have found that combining organic and synthetic fertilizers increases maize output significantly

(Gemechu *et al.*, 2017). Ojimgba (2019) found that the use of 1000 kg/ha mineral fertilizers (NPK 15:15:15) combined with 20 t/ha cacao leaf litter resulted in the maximum cowpea grain production, while topsoil (unamended plot) yielded the least. Unagwu (2014) also reported that using a combination of chicken manure and NPK 15-15-15 fertilizer on maize performed better than using either chicken manure.

Hafiz *et al.* (2020) found that combining synthetic fertilizers and farm yard manure increased grain yield and farm profitability while enhancing grain quality. As a result, combining chemical fertilizer with farmyard manure is a long-term strategy for efficient nutrient usage that enhances synthetic fertilizers' efficiency while minimizing nutrient losses and enhancing crop growth and development (Schoebitz & Vidal, 2016). Mahmood *et al*. (2017) found that using a combination of organic and inorganic fertilizers enhanced maize yield more than using either organic or inorganic fertilizers alone. The higher nutrient usage efficiency of both macro and micronutrients from poultry manure, as well as other growth agents including hormones and macronutrients from NPK, was linked to this (Agbede *et al.*, 2017).

According to Brar *et al.* (2015), combining chemical and organic fertilizers (100 percent NPK + FYM) enhanced soil physical properties and improved soil organic carbon, resulting in greater maize yields. Roba (2018) reported a considerable boost in maize growth and yield when organic and inorganic fertilizers were used together. The effects of poultry manure and NPK fertilizer on crop production and yield components under various cropping systems demonstrated that NPK and poultry manure application considerably enhanced grain yield as well as other indices. The trend was NPK + Pm>NPK>Pm> no fertilizer, with complementary application providing higher growth and yield values than the other treatments (Naher & Paul, 2017).

Moe *et al.* (2017) conducted a study to examine the effect of organic manures and synthetic fertilizers on hybrid rice growth and yield, finding that the combined application of organic manures and synthetic fertilizers was effective in increasing hybrid rice growth and yield. Similarly, several authors have claimed that using a combination of organic and inorganic fertilizers increased rice productivity greatly (Gangmei & George, 2017). Chekolle (2017) studied the synergistic effects of organic and chemical fertilization techniques on bread wheat grain yield. The findings indicated that combining organic manure with N and P fertilizers was more effective than using either N/P or farmyard manure alone. Agegnehu *et al.* (2014) found a similar finding, asserting that combining organic and chemical fertilizers improved wheat yield as well as soil fertility.

2.15 Biochar Systems

Biochar (BC) is a carbon-rich, dark-coloured, porous, and predominantly stable organic substance produced from the pyrolysis of diverse organic materials and industrial wastes (Lu *et al.,* 2020). Biochar can be produced from a variety of materials, including wood, straw and stalks, grasses, nutshells, algal manure, paper mill waste, and sewer sludge (Onwuchekwa *et al.*, 2018). The ash content, elemental composition (C, Ca, P), soil pH, EC, CEC, and surface area of biochar are all influenced by the feedstock variety and production conditions (Kaur & Sharma, 2021). Biochar production is a simple tool that can improve soil fertility by enhancing its physicochemical qualities, reducing organic and agricultural waste, and generating renewable energy (Pituello *et al.,* 2015). Biochar is utilized as a soil modification to boost crop production, boost NUE, and mitigate soil acidity (Feng & Zhu, 2017).

2.15.1 Effect of Biochar on Soil Physical and Chemical Properties

Mosharrof *et al.* (2021) found that the types of feedstock and pyrolysis temperatures during biochar synthesis affected soil available P. Biochar has been a good substance for soil amendment due to its various potential benefits to agriculture and the environment, as well as its ability to hold soil water (Jahromi *et al.*, 2018).

Biochar amendment improves the poor cation exchange capacity (CEC) of acidic soils by increasing the negative charge on soil minerals (Hale *et al.,* 2020). Furthermore, biochar is negatively charged (6–59 cmolc/kg) (Munera-Echeverri *et al.,* 2018), and its addition to soil increases soil CEC. The increased CEC generated by the addition of biochar to tropical soils has been hypothesized to improve NH_4^+ adsorption and, as a result, reduce N leaching (Borchard *et al.,* 2014). Biochar usually contains ash, which is rich in macronutrients such as calcium, magnesium, and potassium, all of which are beneficial to soil health and crop production (Chausali *et al.,* 2021). A field study conducted by Schulz *et al.* (2014) showed that greater aeration and water-holding capacity testified in biochar-amended soils because biochar inputs reduced bulk density, enhanced porosity, and reduce evapotranspiration. The biochar's produced from lignocellulosic-rich feedstocks at higher production temperatures (≤600^{o}C) tend to reduce aggregation in coarse-textured low organic matter-containing soils (Gul *et al.,* 2015).

The field of biochar research is quickly expanding, owing to its potential for soil carbon sequestration and soil fertility improvements (Malghani *et al.*, 2013). BC increases the structure and qualities of the soil in both physical and chemical ways, such as water-holding capacity, organic matter content, aeration condition, soil pH, CEC, and the development of soil aggregates (Khodadad *et al.*, 2011). Rice husk biochar has been shown to enhance soil pH, organic carbon, nitrogen, and sulphur levels while lowering soil bulk density to a desirable level (Karamina & Fikrinda, 2020).

Due to the increased nutrient absorption and sorption potential, Mensah & Frimpong (2018) found that adding BC to soils could provide a potential carbon sink and boost soil nutrient availability for agricultural usage in Ghana. Van Zwieten *et al.* (2010) conducted a thorough study on BC and found that applying paper-mill biochar at a rate of 10 t/ha raised pH, CEC, exchangeable Ca, and total K while decreasing Al availability in a Ferrosol soil while increasing C and exchangeable K in a Calcarosol soil.

2.15.2 Effect of Biochar on Growth and Yield of Maize

Many researchers have discovered that biochar enhances crop productivity of many cereal crops, which include maize; however, Peiris & Weerakkody (2015) discovered that nitrogen uptake increased significantly in maize plants that received biochar, both with and without inorganic fertilizer application, in a study on the effects of biochar amendment on agronomic performances of maize.

Crop productivity is largely determined by factors such as pH, base saturation, exchangeable K, and the Ca/Al ratio. Soil acidity was lowered in a Ultisol using cocoa shell biochar, which increased crop yields (Mosharrof *et al.*, 2021). Maize yield characteristics and water usage efficiency improved by 50 to 100 percent when the biochar application rate was increased from 15 to 20 t/ha (Mahlo, 2020). Similarly, Yargholi & Azarneshan (2014) found that applying 15 tonnes per hectare of cocoa shell biochar improved soil quality and increased crop yields.

Biochar treatment improved wheat and maize grain yields by 18% and 24%, respectively, in a field experiment conducted by Arif *et al.* (2017), compared to a control with no biochar addition. Syuhada *et al.* (2016) reported that the response of maize dry matter increased by 3% for every gram of biochar-treated soil with or without fertilizer and a higher rate of 15 and 20 t/ha increased maize grain yield by 150% and 88 %, respectively, compared with an untreated plot. Jeffery *et al.* (2017) observed that biochar has generated an increase of 25% in yield in acidic soil, and also there has been an increase in maize productivity by 7.5% due to BC application. Brown *et al.* (2015) review report also shows an increase in maize yield by 19% across many studies due to the application of BC.

Several researchers have also indicated that the application of biochar at a range of 20 – 40 t/ha increased the grain yield of maize, cobs weight, stover yield, harvest index, and N concentration in grain (Sara *et al.,* 2018). In a study using BC as a soil amendment on groundnut, it was found that application of BC to acidic red soil favoured good soil physical, chemical, and biological environment, and these positive changes influenced the growth and yield attributes and enhanced groundnut yield by 29% over control (Pandian *et al.*, 2016).

A study on the enhancement of crop growth and yield by bamboo-derived biochar stated that biochar from bamboo showed a more positive effect on the growth and yield of maize; at a treatment dose of 5-10 t/ha biochar bamboo (Situmeang *et al.*, 2015). The results of research conducted by Castellini *et al.* (2015) using biochar amendment showed that BC addition has the potential to increase the production of durum wheat.

2.15.3 Effect of Combined use of Biochar and Inorganic Fertilizers on Crop Performance

As a result of its potential to boost nutrient availability for crop use, biochar is gaining popularity as a soil supplement. As a result, adding biochar to soil has the potential to improve the soil by avoiding nutrient loss, producing chemical-free goods, supporting sustainable agriculture systems, and safeguarding water resources (Onwuchekwa *et al.,* 2018).

Several studies have looked into the impact of combining biochar with inorganic fertilizers on crop performance and when biochar and inorganic fertilizer were applied together, maize growth and yields were higher than when biochar was used alone (Mosharrof *et al.*, 2021). In sandy soils, Uzoma *et al.* (2011) found that applying biochar made from cow manure combined with chemical fertilizer enhanced maize dry matter significantly more than applying chemical fertilizer alone. At a modest rate (10 t/ha), however, there was no difference. When paired with N fertilizer, BC application at 20 and 40 t/ha enhanced maize production by 8.8% and 12.1%, respectively (Zhang *et al.*, 2011). In addition, a study found that applying 5 t/ha poultry litter biochar + 50% NPK fertilizer enhanced cabbage growth and yield by 73% when compared to the control (Ofori *et al.*, 2021).

According to Nguyen & Rondon (2012), biochar mixed with nitrogen fertilizer has been shown to have positive effects on the soil and plant; however, combined application of macronutrients and rice husk biochar has been shown to have positive effects on maize growth and yield (Gandahi *et al.*, 2015). It was also asserted that when compared to mineral fertilizer alone, biochar + compost mixture and biochar addition to inorganic fertilizers significantly enhanced plant growth and yield (Schulz *et al.,* 2014). Lashari *et al.* (2015) further reported that BC application together with chemical fertilizers has been shown to increase agronomic benefits in terms of crop production, especially in soils with low fertility.

According to the findings of Muhammad *et al.* (2014), applying biochar at a rate of 25 t/ha and using an integrated phosphorus source, 50% from organic (FYM or PM) and 50% from inorganic (SSP), increased maize yield and yield components when compared to using only organic and inorganic phosphorus sources. Widowati & Asnah (2014) discovered that the combined application of biochar and KCl fertilizer significantly enhanced maize grain yield compared to the sole amendments.

2.15.4 Effect of Combined use of Biochar and Inorganic Fertilizers on Soil Physical and Chemical Properties

Due to the escalating expense and scarcity of chemical fertilizers, a BC mix to improve and sustain soil fertility is critical. As a result, combining biochar and chemical fertilizer may be an effective management method for boosting crop development and soil quality (Agegnehu *et al.*, 2017).

Ofori *et al.* (2021) discovered that applying 5t/ha poultry litter biochar + 50% (90 kg/ha N, 60 kg/ha P_2O_5, and 60 kg/ha K_2O) raised soil pH, soil organic carbon, accessible phosphorus, and cation exchange capacity by 26.6, 41.4, 296, and 78.7%, respectively, as compared to the control. When BC and chemical fertilizer were administered together, NUE was reported to be higher than when they were applied individually (Alvum-Toll *et al.*, 2011). It was also reported that biochar's conditioning effects in enhancing soil structure and chemical properties contributed to the increased nutrient availability in soils treated with both biochar and inorganic fertilizer (Yu *et al.,* 2017).

According to the research, a combination of biochar and 50% of the recommended dose of NPK was the most efficient for soil conditioning, resulting in increases in soil organic matter and cation exchange capacity, as well as pH (Khalid *et al.*, 2016). For enhancing soil fertility, integrated application of BC and/or chemical fertilizers requires adequate proportions of chemical fertilizers with BC or various BC in a blend (Tammeorg *et al.*, 2014).

BC application in combination with chemical fertilizers has been shown to improve agronomic benefits in terms of crop production, particularly in low-fertility soils, either by acting as a direct source of nutrients or by enhancing nutrient availability through improvements in soil physical, chemical, and biological properties (Lashari *et al.,* 2015). The use of BC and N fertilizer together has been demonstrated to improve soil functions as well as crop N uptake and productivity (Lori *et al.,* 2013). According to Ali *et al*. (2020), applying s60 t/ha of biochar together with 270 kg/ha N improves soil quality while also improving photosynthesis, yield, and yield qualities of noodle rice.

2.15.5 Effect of Combined use of Biochar and Organic Fertilizers on Soil Productivity, Growth, and Yield of Crops

To reduce the unavailability of large volumes of organic fertilizers, it is necessary to blend BC and organic fertilizers. In many locations throughout the world, supplemental usage of organic material (BC) and organic fertilizers has proven to be an effective soil fertility management approach (Kilic *et al.,* 2021). The approach improves crop development and yield and provides a longer-lasting favourable effect on the soil than applying BC or manure alone (Agegnehu *et al.*, 2017).

According to Adekiya *et al.* (2020), combining 15 t/ha BC with 15 t/ha poultry manure (B+PM) increased soil physical and chemical characteristics, growth, and ginger yield when compared to their sole application. Wisnubroto *et al.* (2017) conducted a study on the effect of biochar and organic manure on red chili, concluding that biochar residue mixed with farmyard manure (FYM) increased red chili growth and yield due to the ability to retain nutrients for optimum crop usage. Biochar application in combination with organic manure, according to Wang *et al.* (2017), increases soil C storage and minimizes nitrate and ammonium leaching, as well as increasing nutrient availability to plants and improving plant development and agricultural yields.

According to Lehmann *et al.* (2015), C in biochar is very resistant to microbial decomposition over a long period. However, biochar combined with organic fertilizer has also been emphasized as a soil amendment with considerable promise for sequestering carbon, improving soil fertility, adsorbing organic pollutants, and promoting soil microbial functions (Sistani *et al.,* 2019*)*.

In terms of soil fertility and productivity, several studies have indicated that organic fertilizer combined with biochar performs better than organic fertilizer alone (Sadaf *et al.,* 2017). The soil pH, organic carbon, and enzyme activity were all improved when biochar was combined with dairy manure (Sekaran *et al.,* 2020). Sekaran *et al.* (2020) further reported a significant reduction in the C/N ratio of the soil. Additionally, there are other benefits of incorporating biochar and manure into a soil such as increases in cation exchange capacity (CEC)

(Biederman & Harpole, 2013), increased nutrient retention and availability for plant uptake, especially in highly weathered soils (Ultisols), and increased fertilizer N use efficiency.

2.16 Economic Analysis of Biochar, Chicken Manure and NPK 15:15:15 Fertilizer

A study by Zheng *et al.* (2017) on the impact of biochar compound fertilizer on the economic benefits of maize, showed that when biochar compound fertilizer (BCF) was used instead of chemical fertilizer, maize production improved by 10.7%, with the highest benefit: cost ratio and a 12 % improvement in net revenue and cost-efficiency. Agbede *et al.* (2017) found that applying 20 Mg/ha PM was the most profitable technique. The 20 Mg/ha PM treatment, was more cost-effective and economical in production than the other treatments, as proved by its 58:8 value-to-cost ratio.

Adediran (2018) further stated that the most profitable method was two split applications of 2 t/ha compost enhanced with 30 kg N/ha. The treatment resulted in a good benefit-to-cost ratio (1.9:1) and higher net returns. In comparison to the full rate (90:60:60) or full rate + biochar, Phares *et al.* (2021) found that applying biochar + NPK fertilizer (45:30:30 kg/ha) had a low overall production cost, higher maize grain yield, and high net income.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Location of Experiment

Two field experiments were conducted at different locations of the research field at the Akenten Appiah-Menka University of Skills Training and Entrepreneurial Development (AAMUSTED), Mampong campus. The first experiment was carried out in the minor rainy season from August to December 2021 and the second trial was carried out in the major rainy season from March to July 2022. The experimental site is located between latitudes 7^0 and $8^{'}$ north of the Equator and longitudes 1^0 and $24^{'}$ west of Greenwich Meridian, at an altitude of 457.5 m above sea level (Amartey *et al.*, 2022). The experimental site has GPS coordinates of latitude $7^0$4’38.75196” North and longitude $1^0$23’43.45908” West. The GPS reading at the experimental site is AM-0078-0227.

3.1.1 Climate and Vegetation

Mampong-Ashanti is located in the Forest Savannah transitional zone of Ghana (Amartey *et al., 2*022). The area has a bimodal rainfall distribution, with the major rainy season lasting from early April to July and the minor rainy season occurring from September to November (Pabi *et al.,* 2019). The average annual rainfall in the area is 1270 mm, with a mean relative humidity of 70% and a daily temperature range of 25 °C to 30 °C (MSD, 2017). There is a short dryness in August but the area undergoes a protracted dry season from December to March, which is characterized by high temperatures (Pabi *et al.,* 2019). The vegetation cover of Mampong-Ashanti is of the semi-deciduous type with a thick grass cover. The predominant vegetation is different weed species and a variety of trees and shrubs.

3.1.2 Climatic Conditions at the Experimental Site During the Experiment

Climatic variables (rainfall, temperature, and relative humidity) varied between the two cropping seasons in Asante Mampong. The total rainfall within the experiment period for the 2021 minor cropping season was 676.7mm which lasted from August to December 2021 with the peak in September and October (Appendix 2). The average monthly temperature during the experiment varied from 23.1°C to 31.9 °C, with the highest daily temperature of 34.3 °C occurring in December 2021. The average relative humidity from August to December 2021 was 70.4% (Appendix 2).

In the 2022 major cropping season, the total rainfall was 694.6 mm from March to July, with a peak in June and July. The mean rainfall recorded in the 2022 cropping season was higher than the mean rainfall recorded in the 2021 cropping season. The mean monthly temperature in the 2022 cropping season ranged from 23.4°C to 32.2°C, with the highest daily temperature of 34.0°C occurring in March. With the peak in May and June, the average monthly relative humidity was 70.4% (Appendix 3).

3.1.3 Type of Soil

The soil at the experimental site is of the Bediesi series of the savannah Ochrosol class formed from the Voltaian sandstone of Afram Plains. The soil is classified as Chromic Luvisol in the FAO/UNESCO (2008) Legend system of classification (Asiamah, 1988). The soil pH ranges from 6.5 to 7.0. The soil is sandy loam, well-drained, with a thin layer of organic matter that has a deep yellowish-red colour, is friable, devoid of stones, and has a high-water retention capacity (CSIR-SRI, 1999). Numerous staple crops and commercial crops can be grown on the soil.

3.2 Experimental Design and Treatments

3.2.1 Experimental design

The experimental design used was a 2 x 6 factorial laid in a Randomized Complete Block Design (RCBD) with three replications. Each block contained 12 plots, to which the two varieties were assigned (Omankwa, Obatanpa). The factors were; (i) two (2) varieties of maize (Omankwa and Obatanpa) and (ii) five (5) soil amendment rates and a control (without any amendment).

Table 3.1: Details of Fertilization Treatments

Treatments code	**Soil Amendment Treatments**
T1	Omankwa + 10t/ha CM
T2	Omankwa + 300 kg/ha NPK 15:15:15
T3	Omankwa + 2.5 t/ha GB
T4	Omankwa + 150 kg/ha NPK 15:15:15 + 1.25 t/ha GB
T5	Omankwa + 1.25 t/ha GB + 5 t/ha CM
T6	Omankwa + No fertilizer (Control)
T7	Obatanpa + 10 t/ha CM
T8	Obatanpa + 300 kg/ha NPK 15:15:15
T9	Obatanpa + 2.5 t/ha GB
T10	Obatanpa + 150 kg/ha NPK 15:15:15+ 1.25 t/ha GB
T11	Obatanpa + 1.25 t/ha GB + 5 t/ha CM
T12	Obatanpa + No fertilizer (Control)

CM: Chicken manure GB: *Gliricidia sepium* Biochar

Table 3.2: Treatment Combinations, Composition, and Rate of Application of Fertilizers

Treatments code	Components of treatments	Fertilizer Rates		
		NPK (kg/m^2)	GB (kg/m^2)	CM (kg/m^2)
T1	Omankwa + CM	0	0	15.4
T2	Omankwa + NPK	0.46	0	0
T3	Omankwa + GB	0	3.84	0
T4	Omankwa + NPK + GB	0.23	1.92	0
T5	Omankwa + GB + CM	0	1.92	7.7
T6	No fertilizer (Control)	0	0	0
T7	Obatanpa + CM	0	0	15.4
T8	Obatanpa + NPK	0.46	0	0
T9	Obatanpa + GB	0	3.84	0
T10	Obatanpa + NPK + GB	0.23	1.92	0
T11	Obatanpa + GB + CM	0	1.92	7.7
T12	No fertilizer (Control)	0	0	0

CM: Chicken manure GB: *Gliricidia sepium* Biochar

3.3 Chicken Manure Preparation

The chicken manure used for the field trial was collected from the poultry farm of the AAMUSTED-Mampong campus. The chicken manure was heaped under shade for two weeks and covered with plantain leaves, supported by sticks to dry and decompose before usage and also to minimize the volatilization of N through Ammonia gas.

3.4 Biochar Preparation

Woody branches of *Gliricidia sepium* were slowly pyrolyzed at about 500^{o}C in an anoxic pit reactor prepared at the College of Agriculture Education, AAMUSTED Mampong campus solely for the experiment. The biochar was then crushed and milled leaving it in a powdered form and packaged in a plastic bag until ready for use.

3.5 Land Preparation and Fertilization

The experimental field was marked out. The marked-out field was ploughed, harrowed, leveled, lined, pegged, and soil sampled for routine physical and chemical analyses before planting.

The powdered biochar and the well-decomposed chicken manure were applied a week before sowing. The quantity of biochar and chicken manure needed to be applied according to treatment were uniformly spread on the surface of the plot and incorporated into the soil at about 10 cm deep using a hoe. The NPK (15:15:15) fertilizer was applied 5-7 cm away from the plant by side placement two weeks after sowing.

3.6 Soil, Chicken Manure and Biochar Sampling

Before planting, a representative soil sample was randomly taken from Ap horizon at the uniform depth of 0-20 cm from the research field at the AAMUSTED, Mampong campus. Chicken manure and *Gliricidia sepium* biochar were also sampled for chemical analysis.

3.7 Soil, Chicken Manure and Biochar Analysis

All the soil, manure, and biochar samples were bulked, air-dried, and sub-samples were taken for routine analysis at the Soil Science laboratory of the Department of Crop and Soil Sciences, KNUST, Kumasi- Ghana. The characteristics analyzed include; soil texture, Soil pH, Organic matter, Total Nitrogen, Exchangeable cations (Calcium, Magnesium, Potassium, Sodium) Exchangeable acidity (Al and H), and organic carbon. The soil after air-drying was sieved through a 2 mm sieve and analyzed for chemical properties.

3.7.1 Soil pH

The soil pH was determined by the use of the pH meter. The pH meter was calibrated using two buffer solutions. 10.0g of soil sample was placed in a 50-ml beaker and 20ml of $CaCl_2$ solution was added. The soil was allowed to absorb the $CaCl_2$ solution without stirring. It was then stirred thoroughly for 10 seconds using glass rod. The suspension was stirred for 30 minutes. The pH was recorded on the calibrated pH meter (IITA, 1979).

3.7.2 Organic Carbon / Organic Matter

The Walkley-Black Method was used. 1.0g of the prepared soil sample in a 500-ml conical flask was weighed. 10 ml of 0.16667M $K_2Cr_2O_7$ solution were added to 20ml of concentrated H_2SO_4 containing Ag_2SO_4 (Walkey & Black, 1934). It was mixed thoroughly and the reaction was allowed to complete for 30 minutes. The mixture was diluted with 200ml of water and 10ml of H_3PO_4. 10ml of NaF solution and 2ml of diphenylamine indicator was added. Titration was done with standard 0.5M $FeSO_4$ solutions to brilliant green colour. The blank (without sample) was run simultaneously. The percentage of organic C was given as:

$$\%C = \frac{M \times \langle V_{bl} - V_s \rangle \times 0\cdot003 \times 1\cdot33 \times 100}{g}$$

Where,

M =Molarity of $FeSO_4$

V_{bl} = ml $FeSO_4$ of blank titration

V_s = ml $FeSO_4$ of soil sample titration

g= mass of soil taken in gram

0.003= milli-equivalent weight of C in grams (12/4000)

1.33 = correction factor used to convert the Wet combustion C value to the true C value since the Wet combustion method is about 75 % efficient in estimating C value, (i.e., 100/75 = 1.33).

NB: Organic matter content is determined using the formula:

% organic C X 1.724. (1.724 is the Van Bemellean factor).

3.7.3 Total Nitrogen

Total N was determined using the micro Kjeldahl-technique (AOAC, 1975). 1g of soil sample was weighed and placed in a Kjeldahl flask. 0.7g of copper sulphate, 1.5g of K_2SO_4 and 30ml of H_2SO_4 were added. The set up was heated gently until frothing ceases. It was then boiled briskly until the solution was clear and digested for 30 minutes. The flask was removed from the heater and cooled, 50ml of water was added and was transferred to a distilling flask. 20 – 25ml of standard acid (0.1MHCl) was placed in the receiving conical flask to get an excess of at least 5ml of the acid. 3 drops of methyl red indicator were added and enough water was added to cover the end of the condenser outlet tubes (Bremner & Mulvaney, 1982). Tap water was run through the condenser before 30ml of 35 percent NaOH in the distilling flask was added. The content was heated to distil the ammonia for about 30 – 40 minutes.

The receiving flask was removed and the outlet tube was rinsed into the receiving flask with a small amount of distilled water. The excess acid was titrated in the distillate with 0.1MNaOH. The blank was determined on reagents by using the same quantity of standard acid in a receiving conical flask.

Calculation was done as follows to determine the percent N.

$$\text{Percent N} = \frac{1.401(V_1M_I - V_2M_2) - (V_3M_1 - V_4M_2) \times df}{W}$$

where: V_1= millilitres of standard acid put in receiving flask for samples

V_2= millilitres of standard NaOH used in titration

V_3= millilitres of standard acid put in receiving flask for blank

V_4= millilitres of standard NaOH used in titrating blank

M_1= molarity of standard acid, M_2= molarity of standard NaOH

W= weight of sample taken (1g), df= dilution factor of sample

3.7.4 Available Phosphorus

The available phosphorus was extracted by the Bray P-1 method and determined colorimetrically (Bray & Kutz, 1945). The preparation of the standard curve was done by Bray's method No. 1. The extraction process was carried out by adding 50ml of the bicarbonate extractant to a 100-ml conical flask containing 2.5g of soil sample. 1g of activated carbon was added and shaken for 30minutes on the mechanical shaker and filtered. The development of the colour was carried out by Bray's method No.1 and the calculation was done by the standard curve with fresh molybdate reagent. The colour was measured photometrically at 660nm wavelength. The concentration of P was calculated as: mgP/kg Soil = mg P/ kg in Solution ×50 (Bray & Kutz, 1945).

3.7.5 Available Potassium

This was determined by flame emission photometry the use of the photometric method (IITA, 1979). The standard curve was carried out by setting up the flame photometer by atomizing 0 and 20 Ug K/ml solutions alternatively to reading of 0 and 100. The extraction process was carried out by adding 25ml of the ammonium acetate extractant to a conical flask fixed with a wooden rack containing 5g of soil sample. It was shaken for 5minutes and filtered. The potash in the filtrate was determined with the flame photometer %K=(a-b) × M/Factor. a=MgK/ml in Sample, b=MgK/ml in blank, M=moisture concentration factor. Factor=200/Dil. Factor.

3.7.6 Exchangeable Calcium, Magnesium and Sodium

Five (5) grams of air-dried soil sample was put in a 150-ml conical flask and 25ml of neutral normal ammonium acetate solution was added, mechanically shaken for 5minutes and was filtered through No.1 filter paper. An aliquot of 5ml was taken and 3 crystals of carbamate and 5ml of 16percent NaOH solution and 40mg of indicator powder was added. The set up was titrated with 0.01N EDTA solution until the colour changed gradually from orange-red to reddish-violet (purple). A drop of EDTA solution was added at 5-10 seconds since the change of colour was not instantaneous and the end point was compared with a blank reading (IITA, 1979).

The calculation is: If N_1 is normality of Ca^{2+}/Mg^{2+} and V_1 is volume of aliquot taken and N_2V_2 are the normality and volume of EDTA used, respectively, then:

$N_1V_1=N_2V_2$

$$N_1= \frac{N_2V_2}{V_1} = \frac{\text{Normality of EDTA} \times \text{Vol. of EDTA}}{\text{ml of aliquot taken}}$$

3.7.7 Exchangeable Acidity (Al + H)

Titration method was used. For exchangeable H, 3g of air-dried soil (grind to pass a 2mm sieve) was put into folded filter paper placed on a funnel and place on the Erlenmeyer flask and 50 ml of 1.0 *N* KCl solution was added through the soil in the filter paper and the leachate was collected into the Erlenmeyer flask. 5 drops of phenolphthalein indicator were added to the leachate and titrated with 0.05 *N* NaOH to pink end point. The volume (ml) of NaOH used (V) was then recorded (Mclean, 1965). This was expressed as:

$$\frac{V*0.05*100}{W} = V*1.67$$

where:

V = Titre volume of NaOH used (ml)

Normality of NaOH = 0.05 *N*

W = weight of soil sample used 3 (g)

For exchangeable Al in the soil, 4 ml of 3 *N* NaF was added to the titrated extract and titrated with 0.05 *N* HCl to colourless end point. The volume (ml) of HCl used (V) was recorded (Mclean, 1965).

This was expressed as:

$$= \frac{V*0.05*100}{W} = V*1.67$$

where:

V = Titre volume of HCl used (ml)

Normality of HCl = 0.05 *N*

W = weight of soil sample used (3 g)

3.7.8 Particle Size Distribution (Clay, Silt, Sand) by hydrometer method

51g of air-dried soil (< 2mm) was weighed and transfer into a 250 ml beaker. 50ml of calgon solution and 100 ml of deionized water was dispensed to the soil. The setup was stirred vigorously for 1 min using a glass rod and allowed to stand for 30 min. The suspension was transferred to the mixer and mixed for 15 min at a medium speed. After mixing, the suspension was transferred to the sedimentation cylinder and make up to 1 liter with deionized water and allowed for 1-2mins. The cylinder was place on a flat surface and the time was noted. The soil hydrometer was immediately placed into the suspension and slide slowly into the suspension until it is floating. The first reading was read on the hydrometer (H_1) at 40 seconds after the cylinder was set down and later the hydrometer was removed and the temperature of the suspension was measured with a thermometer (T_1 in ^{o} F). A duplicate reading was taken. The suspension was allowed to stand for 3 hours after the first two hydrometer readings (H_1), before measuring the second reading (H_2). The temperature of the suspension was also read (T_2 in ^{o} F). The textural class was obtained for the soil using the textural triangle.

This was expressed as:

% sand = 100 – (2 × C)

% clay = F + E × 2

% silt = 100 – G

Where:

$A = H_1$, $B = T_{1} - 68 \times 0.2$, $C = A + B - 2$, $D = H_2$, $E = T_{2} - 68 \times 0.2$, $F = D - 2$, $G =$ Sand + Clay

H_1 = average of first two hydrometer readings

T_1 = average of first two temperature readings (^oF)

H_2= second temperature reading

T_2 = second temperature reading (^oF)

3.8 Planting Materials and Planting

Seeds of Omankwa and Obatanpa maize varieties for the first and second experiments were obtained from CSIR-Crops Research Institute in Kumasi- Ghana. The two varieties were chosen because they have high yield capacity and different maturity periods. 'Omankwa' is a 95–day early maturing improved variety and 'Obatanpa' is also a 105–day medium maturing variety and were developed by the Council for Scientific and Industrial Research (CSIR), Crops Research Institute, Kumasi. The grain of Omankwa is white/flint and it has a yield capacity of 4.5 t/ha while the grain of Obatanpa is white/dent with a yield capacity of 4.6 t/ha (Tetteh *et al.*, 2018).

The maize seeds were sown at a spacing of 80 cm between rows and 40 cm within rows at 3 seeds per hill/stand and seedlings were thinned to 2 plants per hill one week after seedling emergence. Each experimental plot contained four (4) rows with twelve (12) plants within each row. There were forty (40) plants within the two central rows of each plot. The sowing of seeds for the minor rainy season was done on 26th September, 2021 and that of the major rainy season was on 13th April, 2022. A total of 36 plots were used for the experiment with individual plot sizes of length and width of 3.2 m and 4.8 m respectively. A path of 0.5 m and

2 m was left between plots and blocks respectively. Each block was made up of twelve (12) plots. The total field size for each season was 43.9 m x 16.4 m (719.96 m^2).

3.9 Agronomic Practices

Weeds were controlled two weeks after planting using the hoe and hand-pulling method. Subsequent weed control was done by hand pulling and hoeing to keep plots free from weeds during the crop growth period every two weeks. The path between plots and blocks was weeded with a cutlass and hoe four times during the experimental period.

3.10 Data Collection and Statistical Analysis

3.10.1 Phenological data

The days to 50% seedling emergence were counted from the day of sowing to when half of the plants within the harvestable rows had emerged. Percentage crop establishment was measured at 4 weeks after planting (WAP). This was achieved by counting the number of plants that had been established within the two central rows of each plot and the percentage crop establishment subsequently estimated.

This was expressed mathematically as follows:

% Plants Establishment = $\frac{Ps}{Pt}\ x\ 100\%$

Where PS= plants that had successfully established, Pt = total number of plants within the two central rows.

3.10.1.2 Days to 50% tasseling and silking

The number of days to 50% tasseling and silking was determined in the two central rows of each plot. The number of days to 50% tasseling and silking was recorded by counting the number of days from sowing when 50% of plants within the two central rows had tasseled or silked.

3.10.2 Vegetative Growth Data

The vegetative growth data taken were plant height, number of leaves per plant, stem diameter, shoot fresh and dry weight, root fresh and dry weight, leaf chlorophyll content, and leaf area.

3.10.2.1 Plant height

Five plants were randomly selected and tagged from the two central rows of each plot for data collection. Plant height was measured with a meter rule, from the ground level to the tip of the apical leaf at two weeks intervals from 4 to 12 WAP and the mean plant height was estimated.

3.10.2.2 Number of leaves per plant

The total number of leaves per plant was counted on the five tagged plants from the two central rows at two weeks intervals from 4 to 12 WAP and the mean leaf number was estimated.

3.10.2.3 Leaf chlorophyll content

The chlorophyll content of leaf was measured from the fifth and sixth leaves of each of the five tagged plants from the two central rows at two weeks intervals from 4 to 10 WAP using a Chlorophyll meter (SPAD-502Plus, Konica Minolta Technologies, Japan).

3.10.2.4 Stem diameter

The stem diameter of the five randomly tagged plants from the two central rows was measured from the base of each plant to about 5cm above ground level at two weeks intervals from 4 to 12 WAP with the aid of a Vernier caliper. The mean stem diameter was then calculated and recorded.

3.10.2.5 Shoot and root fresh weight

Four (4) plants were randomly selected from each plot at 2 weeks intervals from 4 to 10 WAP. The plants were carefully uprooted from the soil without tearing the roots. All the adhering soil were washed off and dried under shade for some time. The roots were separated from the shoots and destructively sampled for root fresh weight. The shoot plus the leaves were also destructively sampled and weighed for fresh weight using an electronic weighing scale and the mean values for root and shoot were estimated.

3.10.2.6 Shoot and root dry weight

After destructive sampling of the four (4) plants from each plot for the shoot and root fresh weight gain, 200 g samples per plot were placed in a paper envelope and oven-dried at 72 °C for 72 hours to remove all moisture. Dried samples were then weighed using an electronic weighing scale and the mean dry weight was subsequently estimated. The data were collected at 2 weeks intervals from 4 to 10 WAP.

3.10.3 Yield and Yield Components Data

Yield and yield components data were taken from the harvestable area for determination of the number of cobs per plant and per plot, cob length, cob diameter, number of plants harvested, Grain yield (kg/ha), 100-seed weight, harvest index, and number of filled and unfilled cobs.

3.10.3.1 Number of plants harvested

The total number of plants within the two central rows of each plot was counted on the day of harvest and the mean was estimated.

3.10.3.2 Number of cobs per plant and per plot

The number of cobs for the tagged plants from the two central rows was counted and the mean was estimated as the number of cobs per plant. Cobs from tagged and untagged plants from the two central rows were counted and the mean was estimated as the total number of cobs per plot.

3.10.3.3 Cob length

Five (5) cobs were randomly selected from the two central rows of each plot at harvest and cob length was measured from the base of the cob to the tip with a meter rule. The mean was then estimated.

3.10.3.4 100-seed weight

Hundred grains were randomly counted from the two central rows of each plot after harvest and shelling, weighed, and the mean computed.

3.10.3.5 Number of filled and unfilled cobs

The numbers of filled and unfilled cobs were counted from the two central rows of each plot at harvest and the mean was computed.

3.10.3.6 Cob diameter

Five (5) cobs were randomly selected from the two central rows of each plot. The cob diameter was measured at the widest part of the cob using a Vernier caliper. The treatment means were estimated.

3.10.3.7 Grain yield

The grain yield per plot was calculated in kg/ha using the formula as described below by Amanullah *et al*. (2019) as follows: Grain yield (kg/ha) = $\frac{Grain\ yield\ (kg)}{Harvestable\ area\ (m^2)} \times 10000m^2$

3.10.3.8 Harvest index

All maize stover from the two central rows was weighed using a salter suspended weigher (model number 235) at harvest. The grain weight was estimated and used to determine the harvest index. The harvest index (HI) was calculated using the expression as described below by Amanullah *et al*. (2019) as follows:

Harvest index = $\frac{Grain\ yield}{Biological\ yield}$

3.11 Cost Benefit Analysis of Treatments

A cost-benefit analysis was done to determine the relative economic benefit of the applied treatments using 2021 and 2022 annual market prices. The yields were adjusted by 10% downwards due to management level variability between a researcher and a farmer

(CIMMYT, 1998). Costs of farm services were taken at the Asante Mampong market in the Mampong Municipality of the Ashanti Region of Ghana. This was due to the location of the field trials and also all inputs were obtained from there. The adjusted yield, total gross benefit, variable cost (fertilizer, application, and transportation costs), total variable cost (TVC), net benefit (NB), and marginal rate of return were also estimated (Essilfie, 2015).

1. Adjusted yield (t/ha) = 90 % x yield (t/ha) obtained
2. Total Gross Benefit = Adjusted yield (t/ha) x farm gate price
3. Total variable cost= fertilizer cost + application cost + transportation cost
4. Net benefit = Total gross benefit – Total variable cost
5. Marginal rate of return (MRR) (%) =$\frac{\Delta \text{net benefit}}{\Delta \text{total variable cost}}\ x\ 100$

3.12 Data Analysis

All data collected were analyzed using Analysis of Variance (ANOVA). The data obtained were analyzed using the GenStat Release 18.1 (PC/Windows 8) statistical package, Copyright 2015, VSN International Ltd. Registered to ICARDA. The differences between treatment means were separated and compared using Tukey’s Honestly Significant Difference (HSD) at 5% level of probability.

CHAPTER FOUR

4.0 RESULTS

4.1 Soil, Chicken Manure and Biochar Analysis

4.1.1 Soil Characteristics

Table 4.1 shows the chemical and physical characteristics of the soils at the experimental site for experiments I and II. Using the classification interpretation guide by CSIR-Soil Research Institute (Appendix 1), during the 2021 minor growing season the soil was slightly acidic (6.05). Organic matter content (1.06) level was low. Nitrogen (0.18) level was moderate.

In the 2022 major season, the soil was slightly acidic (6.50). Organic matter content (1.75) was moderate. Total nitrogen levels (0.10) were low. In 2021 minor and 2022 major growing seasons, available P levels (7.45 and 6.24) were low. The exchangeable bases (Ca, Mg, and Na) levels were low per the soil analytical data interpretation guide of CSIR-Soil Research Institute (Appendix 1). Total K levels in both seasons were low. The textural class of soils for both 2021 minor and 2022 major cropping seasons was sandy-loam.

Table 4.1: Chemical and Physical Properties of the Background Soil

Soil Samples	pH (H_2O)	P mg/kg	N (%)	Exch. Bases (cmol/kg)				Exch. Acidity (cmol/kg)		% Org. C.	% Org. M.
				K	Ca	Mg	Na	Al	H		
Exp. 1	6.05	7.45	0.18	0.13	1.65	0.53	0.02	0.40	0.53	0.82	1.06
Exp. 2	6.50	6.24	0.10	0.19	1.87	1.02	0.07	0.43	0.58	1.22	1.75

	Particle size analysis			
	% Sand	% Clay	% Silt	Textural class
Exp. 1	79.07	9.98	10.95	Sandy loam
Exp. 2	77.87	10.12	12.01	Sandy loam

4.1.2 Chemical Characteristics of Chicken Manure and *Gliricidia sepium* biochar

Table 4.2 shows the chemical characteristics of chicken manure and *Gliricidia sepium* biochar used in 2021 minor and 2022 major cropping seasons. During the 2021 minor and 2022 major growing seasons, the chicken manure was slightly alkaline and alkaline respectively. Total P, Ca, and Mg levels were low in both cropping seasons. However, total N and K levels were relatively high in experiments I and II. The *Gliricidia sepium* biochar was alkaline. The biochar was observed to have moderate N and K levels. P, Ca, and Mg levels were low (Appendix 1).

Table 4.2: Chemical Properties of Chicken Manure and *Gliricidia sepium* biochar used for the Experiment

Properties	Chicken manure		
	Experiment I	Experiment II	Biochar
pH (H_2O)	7.16	7.84	8.5
N (%)	2.73	4.02	0.13
P (%)	2.09	3.41	0.28
Org. C (%)	40.95	38.2	50.2
C: N ratio	15.0	9.50	386.15
Ca (%)	1.63	2.89	0.17
Mg (%)	0.59	1.09	0.14
K (%)	2.68	2.93	0.40

4.2 Phenology

4.2.1 Days to 50% Emergence

The result on number of days to 50% emergence as influenced by biochar, chicken manure, and NPK fertilizer is presented in Table 4.3. During the 2021 minor season, there was no significant ($P \geq 0.05$) difference between Omankwa and Obatanpa in number of days to 50% emergence.

In the major season (2022), there was a significant ($P \leq 0.05$) difference between Obatanpa and Omankwa in number of days to 50% emergence. Omankwa emerged almost a day (1 day) earlier than Obatanpa. In both seasons, 1.25 t/ha GB + 5 t/ha CM emerged a day (4.00) earlier than the control (4.83 days) in number of days to 50% emergence. In both seasons, biochar, chicken manure, and NPK fertilizer interaction did not significantly influence number of days to 50% emergence for the two varieties. There was no significant ($P \geq 0.05$) difference between seasons and season x variety x fertilizer rates interaction (Table 4.3).

4.2.2 Percentage Crop Establishment

The result on percentage crop establishment as influenced by biochar, chicken manure, and NPK fertilizer is presented in Table 4.3. During the minor season (2021), there was no significant ($P \geq 0.05$) difference between Omankwa and Obatanpa in percentage crop establishment. There was a significant ($P \leq 0.05$) difference between the fertilizer rates. 1.25 t/ha GB + 5 t/ha CM treated plot produced significantly ($P \leq 0.05$) higher (98.75%) percentage crop establishment than the control plot which recorded the lowest (91.67%). Omankwa grown on 1.25 t/ha GB + 5 t/ha CM treated plot had the highest (100.0%) percentage crop establishment that was significantly ($P \leq 0.05$) different from the control plot which recorded the lowest (89.17%). Omankwa and Obatanpa grown on 300 kg/ha NPK 15:15:15, 2.5 t/ha GB, 1.25 t/ha GB+5 t/ha CM and 10 t/ha CM plot respectively had the same (97.50%) percentage crop establishment (Table 4.3).

For the 2022 major season, there was no significant ($P \geq 0.05$) difference between the two maize varieties (Omankwa and Obatanpa) in percentage crop establishment. There was a significant ($P \leq 0.05$) difference between the fertilizer rates.

Application of 10 t/ha CM produced significantly (P≤0.05) higher (99.17%) percentage crop establishment than the control plot which recorded the lowest (92.50%). Omankwa grown on 10 t/ha CM plot recorded the highest (100.0%) percentage crop establishment that was significantly (P≤0.05) different from the control plot with the lowest mean value of (92.50%). Obatanpa grown on 1.25 t/ha GB + 5 t/ha CM plot produced significantly (P≤ 0.05) high (99.17%) percentage crop establishment than Obatanpa grown on the control plot with the least mean value of (92.50%). There was no significant (P≥0.05) difference between seasons and season x variety x fertilizer rates interaction (Table 4.3).

Table 4.3: Days to 50% Emergence and Percentage Crop Establishment as affected by biochar, chicken manure and NPK fertilizer during 2021 Minor and 2022 Major Seasons

Treatment	Days to 50% emergence		Percentage crop establishment	
	2021 minor season	2022 major season	2021 minor season	2022 major season
Variety				
Omankwa	4.33	4.33b	96.94	96.94
Obatanpa	4.50	4.61a	96.67	96.81
HSD ($P \leq 0.05$)	**NS**	**0.27**	**NS**	**NS**
Fertilizer rates				
10 t/ha CM	4.00b	4.17ab	98.33a	99.17a
300 kg/ha NPK 15:15:15	4.50ab	4.50ab	97.50a	95.00bc
2.5 t/ha GB	4.67ab	4.83a	97.50a	98.33a
150 kg/ha NPK + 1.25 t/ha GB	4.50ab	4.50ab	97.50a	97.50ab
1.25 t/ha GB + 5 t/ha CM	4.00b	4.00b	98.75a	98.75a
No fertilizer (Control)	4.83a	4.83a	91.67b	92.50c
HSD ($P \leq 0.05$)	**0.68**	**0.69**	**4.14**	**3.25**
Interaction (V X F)				
Omank. **x** 10 t/ha CM	4.00	4.00	99.17a	100.00a
Omank. **x** 300 kg/ha NPK 15:15:15	4.67	4.33	97.50a	95.00ab
Omank. **x** 2.5 t/ha GB	4.67	4.67	97.50a	99.17a
Omank. **x** 150 kg/ha NPK + 1.25 t/ha GB	4.00	4.00	98.33a	96.67ab
Omank. **x** 1.25 t/ha GB + 5 t/ha CM	4.00	4.00	100.00a	98.33a
Omank. **x** No fertilizer (Control)	4.67	5.00	89.17b	92.50b
Obatan. **x** 10 t/ha CM	4.00	4.33	97.50a	98.33a
Obatan. **x** 300 kg/ha NPK 15:15:15	4.33	4.67	97.50a	95.00ab
Obatan. **x** 2.5 t/ha GB	4.67	5.00	97.50a	97.50ab
Obatan. **x** 150 kg/ha NPK + 1.25 t/ha GB	5.00	5.00	95.83ab	98.33a
Obatan. **x** 1.25 t/ha GB + 5 t/ha CM	4.00	4.00	97.50a	99.17a
Obatan. **x** No fertilizer (Control)	5.00	4.67	94.17ab	92.50b
HSD ($P \leq 0.05$)	**NS**	**NS**	**6.83**	**5.37**
CV (%)	**8.59**	**8.68**	**2.38**	**1.87**

x – interaction CM – Chicken manure GB – *Gliricidia sepium* biochar

Variety (V) = 0.19** NS
Fertilizer rates (Fr.) = 0.47** 2.60**
Season (S) = NS NS
S x V = NS NS
Fr. x V = 0.77** NS
Fr. x S = NS NS
S x Fr. x V = NS NS

4.2.3 Days to 50% Tasseling

The result on number of days to 50% tasseling as influenced by biochar, chicken manure, and inorganic fertilizer is presented in Table 4.4. During the minor season (2021), there was a significant ($P \leq 0.05$) difference between Omankwa and Obatanpa in number of days to 50% tasseling. Omankwa tasseled seven (7) days earlier than Obatanpa. There was a significant ($P \leq 0.05$) difference between the fertilizer rates. Plot treated with 10 t/ha CM tasseled almost five days (47.33 days) earlier than the control plot (51.83 days). Omankwa grown on 10 t/ha CM plot tasseled three days (44.67 days) earlier than plants planted on the control plot (48) days. Obatanpa grown on 10 t/ha CM plot tasseled six days (50 days) earlier than plants planted on the control plot (55.67 days) (Table 4.4). There was, however, no significant ($P \geq 0.05$) difference between the amended plots in days to 50% tasseling in both maize varieties.

In the major season (2022), there was a significant ($P \leq 0.05$) difference between the two varieties (Omankwa and Obatanpa) in number of days to 50% tasseling with Omankwa tasseling five days (51.33 days) earlier than Obatanpa (55.78 days). There was a significant ($P \leq 0.05$) difference between some of the fertilizer treatments. Plot treated with 10t/ha CM tasseled four days (51.33 days) earlier than the control plot (55.33 days). Omankwa grown on 10 t/ha CM plot recorded the least (49.33) number of days to 50% tasseling that was not significantly ($P \geq 0.05$) different from Omankwa grown on the control plot which tasseled four days later (53 days). Although, Obatanpa grown on amended plots showed differences in days to 50% tasseling, no significant ($P \geq 0.05$) difference, however, existed between the treatment means and the control. There was a significant ($P \leq 0.05$) difference between seasons in days to 50% tasseling during the 2022 major season which was significantly higher than those recorded in the 2021 minor season. There was no significant (P≥0.05) difference between season x variety x fertilizer rates interactions (Table 4.4).

4.2.4 Days to 50% Silking

The result on number of days to 50% silking as influenced by biochar, chicken manure, and inorganic fertilizer is presented in Table 4.4. During the minor season (2021), there was a significant (P≤0.05) difference between Omankwa and Obatanpa in number of days to 50% silking. Omankwa silked seven days earlier than Obatanpa. There was a significant (P≤0.05) difference between the fertilizer rates. 10 t/ha CM treated plot silked five days (52.33 days) earlier than the control plot (56.50 days). Omankwa grown on 10 t/ha CM and 1.25 t/ha GB + 5 t/ha CM plot recorded the least (50.00 and 50.33 days) number of days to 50% silking and was not significantly (P≥0.05) different from Omankwa grown on other amended plots. Obatanpa grown on 10t/ha CM plot silked six days (54.67 days) earlier than the control plot (61 days). There was no significant (P≥0.05) difference between Obatanpa planted on other amended plots except 1.25t/ha GB + 5 t/ha CM in days to 50% silking.

In 2022 major season, there was a significant (P≤0.05) difference between the two maize varieties (Omankwa and Obatanpa) in number of days to 50% silking. Omankwa silked five days (56 days) earlier than Obatanpa (61 days). Omankwa grown on unamended and 300 kg/ha NPK 15:15:15 treated plots recorded the highest (59) number of days to 50% silking than other amended plots with Omankwa. Obatanpa grown on 10 t/ha CM plot produced the least (57.67) number of days to 50% silking and was significantly (P≤0.05) different from other amended and the control plot which was late (64.67 days) to silk. There was a significant (P≤0.05) difference between seasons with days to 50% silking in the 2022 major season which was significantly higher than those recorded in the minor season (2021). There was no significant ($P \geq 0.05$) difference between season x variety x fertilizer rates interactions in number of days to silking (Table 4.4).

Table 4.4: Days to 50% Tasseling and Silking as affected by biochar, chicken manure and NPK fertilizer during 2021 Minor and 2022 Major Seasons

Treatment	Days to 50% tasseling		Days to 50% silking	
	2021 minor season	2022 major season	2021 minor season	2022 major season
Variety				
Omankwa	47.28b	51.33b	51.39b	56.11b
Obatanpa	53.89a	55.78a	58.44a	61.22a
HSD ($P \leq 0.05$)	**0.56**	**1.17**	**0.86**	**1.56**
Fertilizer rates				
10 t/ha CM	47.33c	51.33b	52.33b	54.50c
300 kg/ha NPK 15:15:15	51.17a	54.33ab	55.50a	60.17ab
2.5 t/ha GB	51.67a	54.00ab	55.67a	59.50ab
150 kg/ha NPK + 1.25 t/ha GB	52.00a	53.67ab	56.33a	59.33ab
1.25 t/ha GB + 5 t/ha CM	49.50b	52.67ab	53.17b	56.67bc
No fertilizer (Control)	51.83a	55.33a	56.50a	61.83a
HSD ($P \leq 0.05$)	**1.44**	**3.05**	**2.26**	**4.06**
Interaction (V X F)				
Omank. **x** 10 t/ha CM	44.67e	49.33d	50.00e	51.33d
Omank. **x** 300 kg/ha NPK 15:15:15	48.00cd	52.67abcd	52.00de	58.67abc
Omank. **x** 2.5 t/ha GB	48.00cd	52.00bcd	51.33de	58.33abc
Omank. **x** 150 kg/ha NPK + 1.25 t/ha GB	48.67cd	50.67cd	52.67cde	56.33bcd
Omank. **x** 1.25 t/ha GB + 5 t/ha CM	46.33de	50.33cd	50.33e	53.00d
Omank. **x** No fertilizer (Control)	48.00cd	53.00abcd	52.00de	59.00abc
Obatan. **x** 10 t/ha CM	50.00c	53.33abcd	54.67cd	57.67bcd
Obatan. **x** 300 kg/ha NPK 15:15:15	54.33ab	56.00ab	59.00ab	61.67ab
Obatan. **x** 2.5 t/ha GB	55.33a	56.00ab	60.00a	60.67ab
Obatan. **x** 150 kg/ha NPK + 1.25 t/ha GB	55.33a	56.67ab	60.00a	62.33ab
Obatan. **x** 1.25 t/ha GB + 5 t/ha CM	52.67b	55.00abc	56.00bc	60.33ab
Obatan. **x** No fertilizer (Control)	55.67a	57.67a	61.00a	64.67a
HSD ($P \leq 0.05$)	**2.38**	**5.04**	**3.73**	**6.70**
CV (%)	**1.59**	**3.17**	**2.29**	**3.85**

x – interaction   CM – Chicken manure   GB – *Gliricidia sepium* biochar

Variety (V)	= 0.73**	0.92**
Fertilizer rates (Fr.)	= 1.87**	2.35**
Season (S)	= 0.73**	0.92**
S x V	= 1.37**	1.72**
Fr. x V	= NS	NS
Fr. x S	= NS	NS
S x Fr. x V	= NS	NS

4.3 Vegetative growth

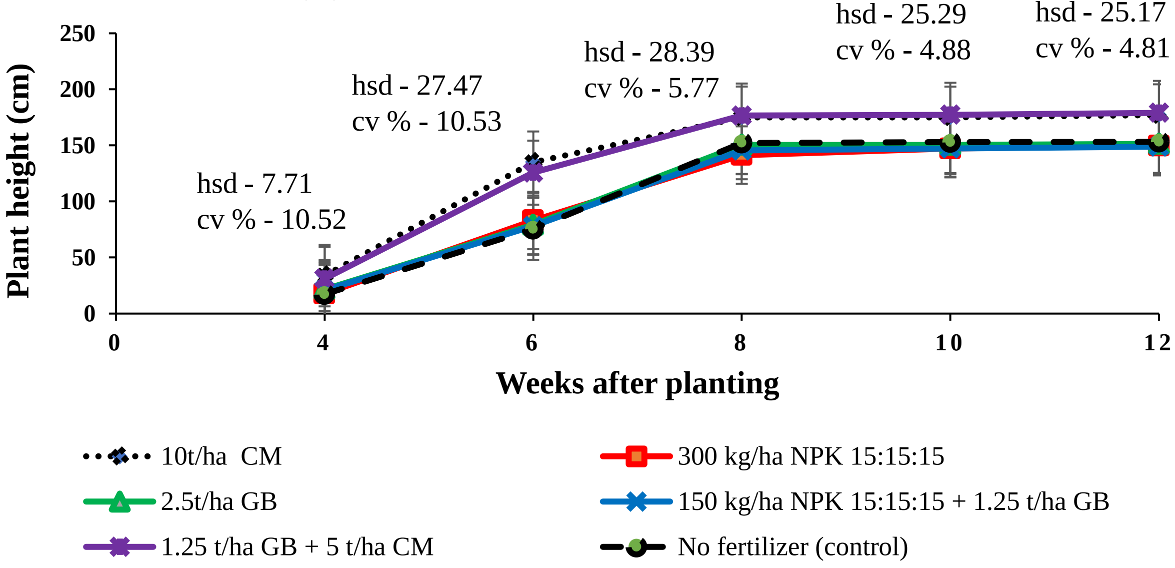
4.3.1 Plant height

Plant height as influenced by biochar, chicken manure, and NPK fertilizer is presented in Figures 4.1 and 4.2. In the 2021 minor season, application of 10 t/ha CM to Omankwa differed significantly (P≤0.05) from the control in plant height from 4 to 6 WAP (Fig 4.1). Application of 150 kg/ha NPK 15:15:15 + 1.25 t/ha GB and 300 kg/ha NPK 15:15:15 to Omankwa recorded the lowest plant height from 8 to 12 WAP (Fig 4.1). Application of 1.25 t/ha GB + 5 t/ha CM to Omankwa which had the highest plant height differed significantly (P≤0.05) from other amended and the control plots from 8 to 12 WAP. The tallest (179.00 cm) plant was recorded by 1.25 t/ha GB + 5 t/ha CM whereas the shortest (148.87 cm) was recorded by 150kg/ha NPK + 1.25 t/ha GB at 12 WAP (Fig 4.1). In the 2022 major season, application of 1.25 t/ha GB + 5 t/ha CM to Omankwa differed significantly (P≤0.05) from the control in plant height at 4 WAP (Fig 4.1). Omankwa grown on amended plots did not differ significantly (P≥0.05) from the control plot in plant height from 6 to 8 WAP (Fig 4.1). Omankwa grown on 10 t/ha CM plot differed significantly in plant height from other amended and control plots from 10 to 12 WAP

In the 2021 minor season, Obatanpa grown on amended plots differed significantly (P≤0.05) from the control plot in plant height from 4 to 12 WAP (Fig 4.2). The application of 10 t/ha CM to Obatanpa gave significantly taller plant height than other amended and control plots from 4 to 12 WAP. Obatanpa grown on 2.5 t/ha GB recorded the shortest (176.90 cm) plant height at 12 WAP (Fig 4.2). At 4 WAP during the 2022 major season, there was no significant (P≥0.05) difference between Obatanpa grown on amended and unamended plots (Fig 4.2). Obatanpa x amended soils differed significantly (P≤0.05) from the control in plant height from

6 to 12 WAP. Obatanpa grown on 10 t/ha CM plot had the tallest plant height (225.68 cm) and differed significantly from the other amended and the control plots at 12 WAP (Fig. 4.2). Obatanpa grown on control plot had the least plant height at 12 WAP.

(a) Omankwa, minor season



(b) Omankwa, major season

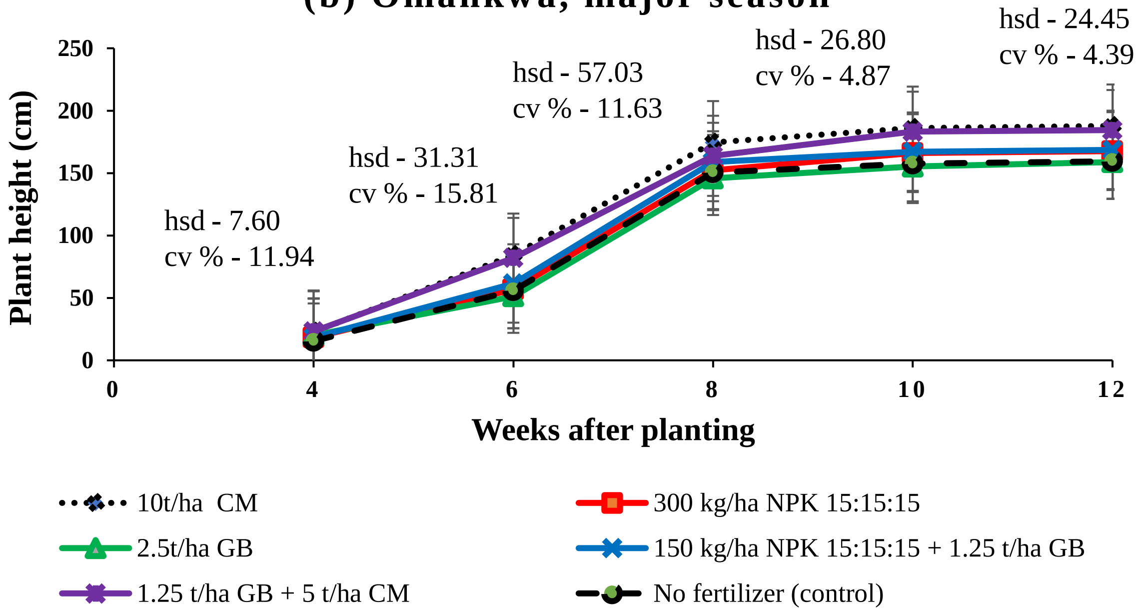
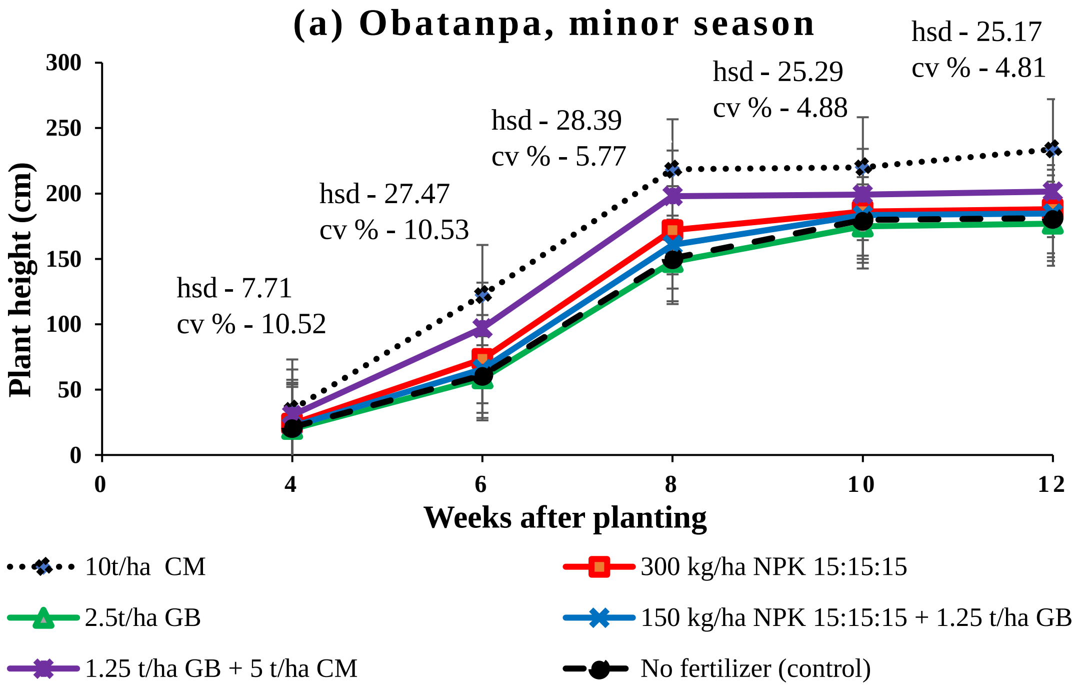
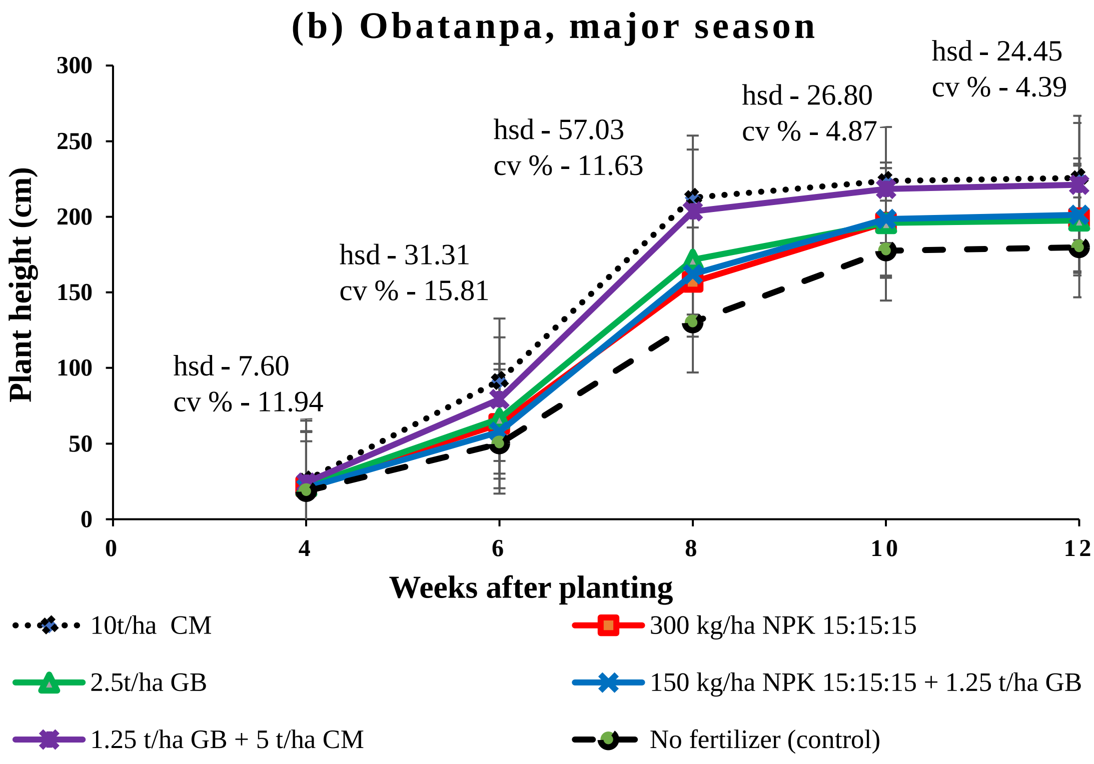


Figure 4.1: Plant height of Omankwa maize variety as affected by biochar, chicken manure and NPK fertilizer during 2021 minor and 2022 major seasons



(a) Obatanpa, minor season



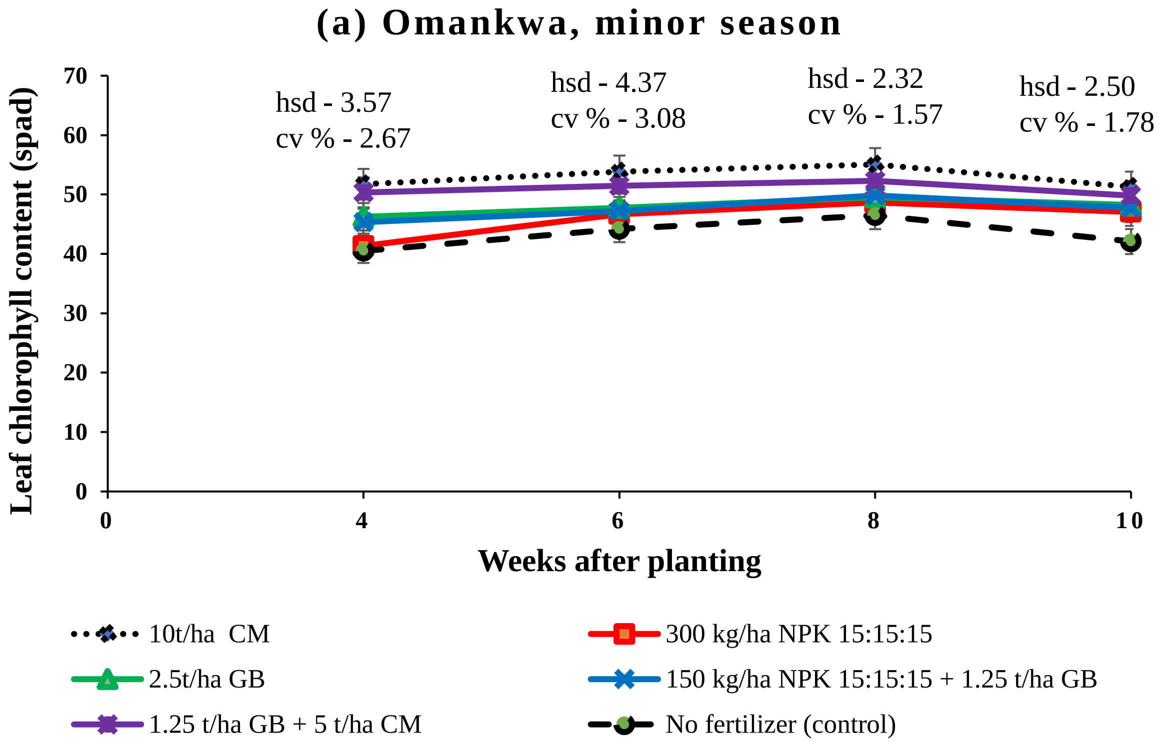
(b) Obatanpa, major season

Figure 4.2: Plant height of Obatanpa maize variety as affected by biochar, chicken manure and NPK fertilizer during 2021 minor and 2022 major seasons

4.3.2 Leaf Chlorophyll Content

The leaf chlorophyll content as influenced by biochar, chicken manure, and NPK fertilizer is presented in Figures 4.3 and 4.4. During the 2021 minor season, application 10 t/ha CM and 1.25 t/ha GB + 5 t/ha CM to Omankwa differed significantly ($P \leq 0.05$) from the control in leaf chlorophyll content from 4 to 10 WAP (Fig. 4.3). Omankwa under 10 t/ha CM recorded the highest (51.2 spad) leaf chlorophyll content whereas the lowest (42.08 spad) was recorded by the control plot at 10 WAP (Fig. 4.3). In the 2022 major season, there was no significant difference between Omankwa grown on the amended plots, however, control plot differed significantly ($P \leq 0.05$) from 10 t/ha CM in leaf chlorophyll content from 4 to 6 WAP (Fig. 4.3). Application of 10 t/ha CM to Omankwa differed significantly ($P \leq 0.05$) from the other unamended plot in leaf chlorophyll content from 8 to 10 WAP. The lowest (43.52 spad) leaf chlorophyll content was recorded by the control plot at 10 WAP with 10 t/ha CM recording the highest (51.25 spad) (Fig. 4.3).

Application of amendment to Obatanpa except 2.5 t/ha GB differed significantly from the control in leaf chlorophyll content at 4 WAP during 2021 minor season (Fig. 4.4). Application of 10 t/ha CM and 1.25 t/ha GB + 5 t/ha CM to Obatanpa which had the highest leaf chlorophyll content differed significantly from the control plot from 6 to 10 WAP (Fig. 4.4). In the 2022 major season, application of 10 t/ha CM and 1.25 t/ha GB + 5 t/ha CM to Obatanpa differed significantly from the control in leaf chlorophyll content from 4 to 10 WAP (Fig. 4.4). Obatanpa grown on 10 t/ha CM plot had the highest (58.14 spad) leaf chlorophyll content that differed significantly from the control plots with the least (49.33 spad) at 8 WAP. There was, however, a substantial reduction of leaf chlorophyll content at 10 WAP in both seasons (Fig. 4.4).



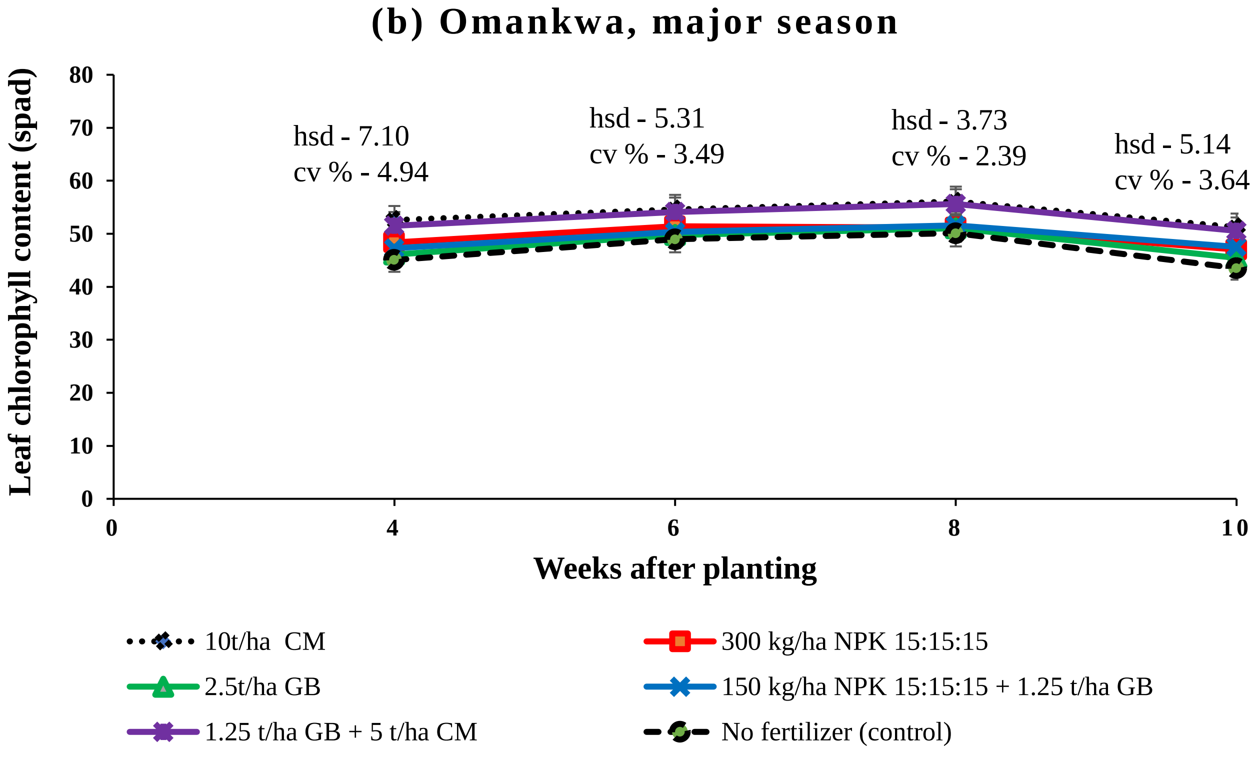
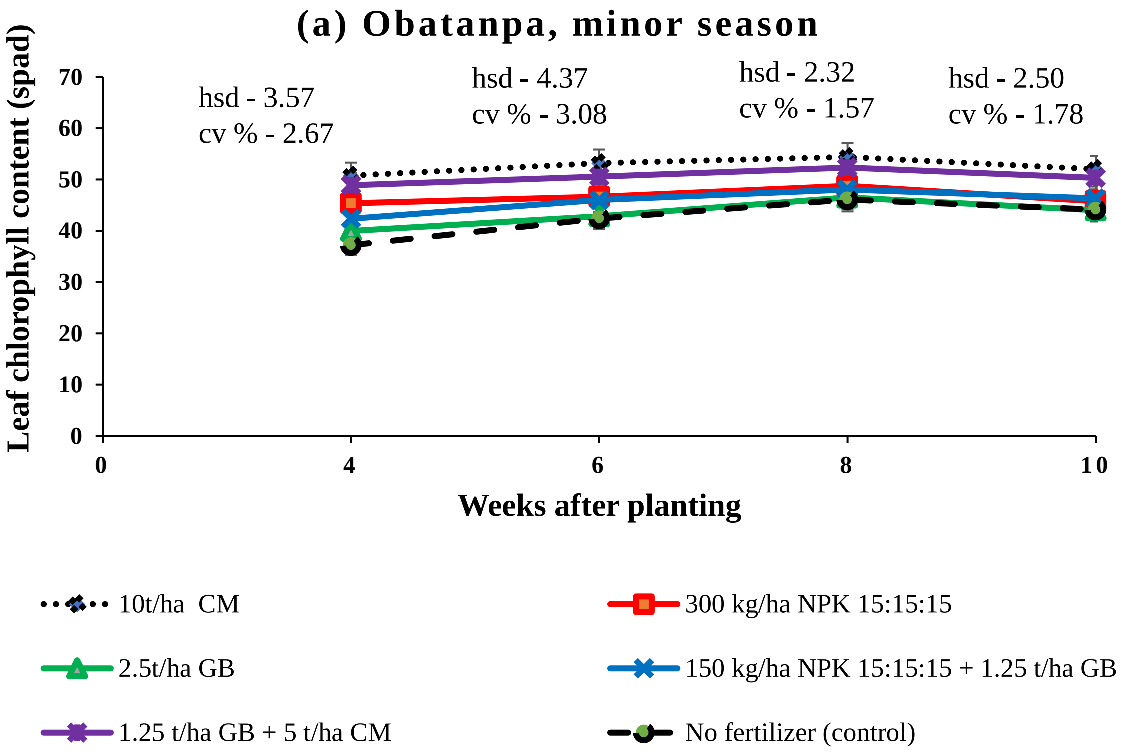


Figure 4.3: Leaf chlorophyll content of Omankwa maize variety as affected by biochar, chicken manure and NPK fertilizer during 2021 minor and 2022 major seasons


(a) Obatanpa, minor season

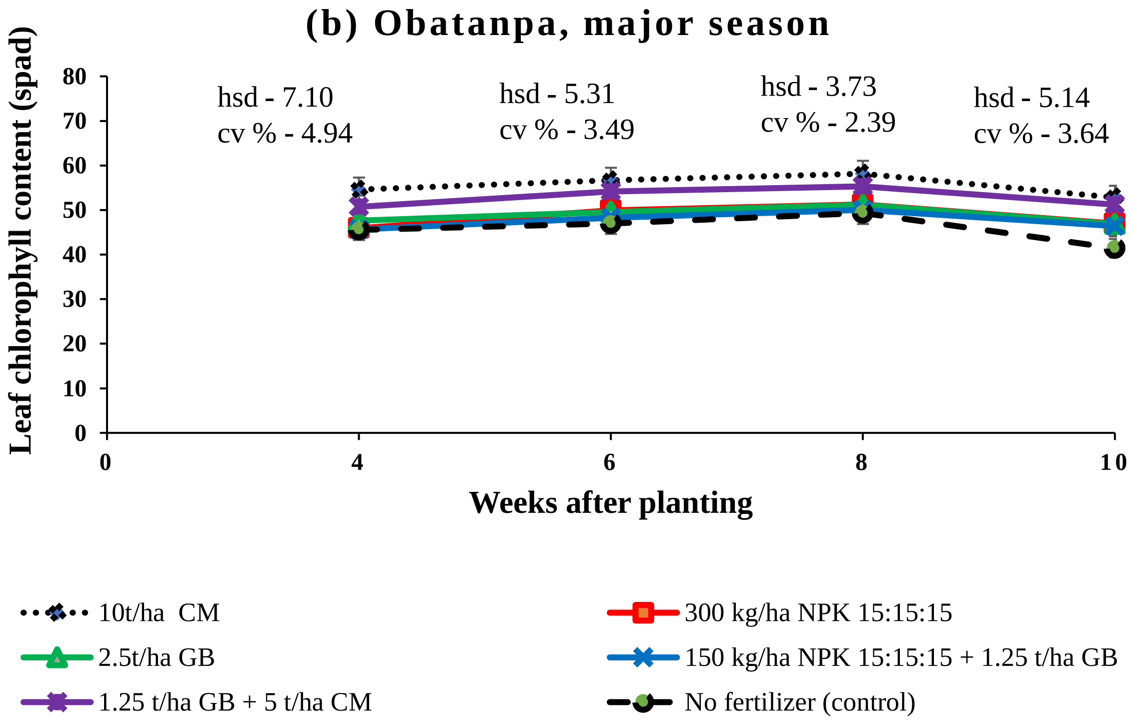

(b) Obatanpa, major season

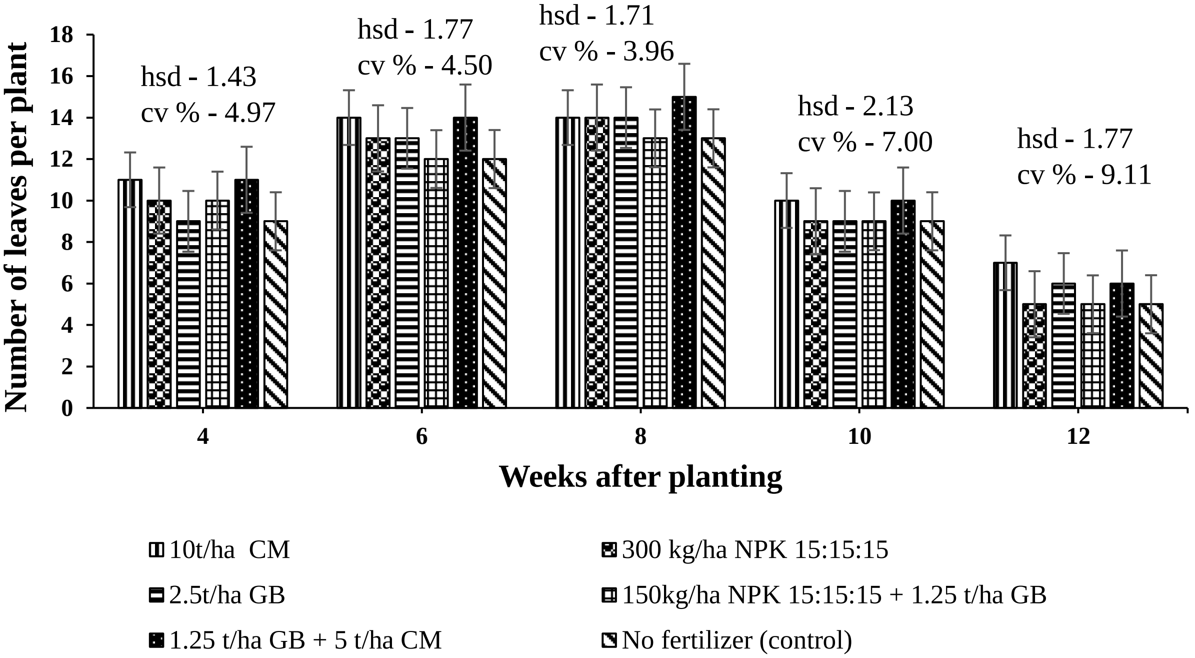
Figure 4.4: Leaf chlorophyll content of Obatanpa maize variety as affected by biochar, chicken manure and NPK fertilizer during 2021 minor and 2022 major seasons

4.3.3 Number of leaves per Plant

The result on number of leaves per plant as influenced by different amendment rates is presented in Fig. 4.5 and 4.6. During the minor season (2021), Omankwa under amended plots and control did not differ significantly ($P \geq 0.05$) in number of leaves per plant from 6 to 8 WAP (Fig. 4.5). Omankwa grown on 10 t/ha CM plots differed significantly ($P \leq 0.05$) in number of leaves per plant from the control plot at 4 WAP, 10 WAP and 12 WAP. Application of 10 t/ha CM to Omankwa gave the highest (7) number of leaves per plant and differed significantly from the control plot and 150 kg/ha NPK 15:15:15 + 1.25 t/ha GB treated plot at 12 WAP (Fig. 4.5). In 2022 major cropping season, Omankwa grown on amended plots differed significantly in number of leaves per plant from the control plots from 4 to 12 WAP except at 10 WAP (Fig. 4.5). Omankwa grown on 10 t/ha CM produced the highest number of leaves per plant from 4 to 12 WAP. The control gave the lowest number of leaves per plant from 4 to 12 WAP (Fig. 4.5). However, Omankwa grown on 2.5t/ha GB gave the least number of leaves per plant at 10 WAP (Fig. 4.5).

Obatanpa grown on amended plots did not differ significantly in number of leaves per plant from the control from 10 to 12 WAP during the 2021 minor season (Fig. 4.6). However, Obatanpa grown on amended plots differed significantly in number of leaves per plant from the control at 4 to 8 WAP. Application of 10 t/ha CM and 1.25 t/ha GB + 5 t/ha CM to Obatanpa gave the highest (16) number of leaves per plant at 8 WAP (Fig. 4.6). In 2022 major cropping season, Obatanpa grown on amended and control plots differ significantly ($P \leq 0.05$) in number of leaves per plant from 4 to 12 WAP (Fig. 4.6). Obatanpa grown on 10 t/ha CM produced the highest number of leaves per plant from 4 to 12 WAP followed by 1.25 t/ha GB +5 t/ha CM at the same growing period. The control gave the lowest number of leaves per plant from 4 to 12 WAP (Fig. 4.6). Both maize varieties grown on 10 t/ha CM and 1.25 t/ha GB + 5 t/ha CM produced the highest number of leaves at 8 WAP in both cropping seasons.

(a) Omankwa, minor season



(b) Omankwa, major season

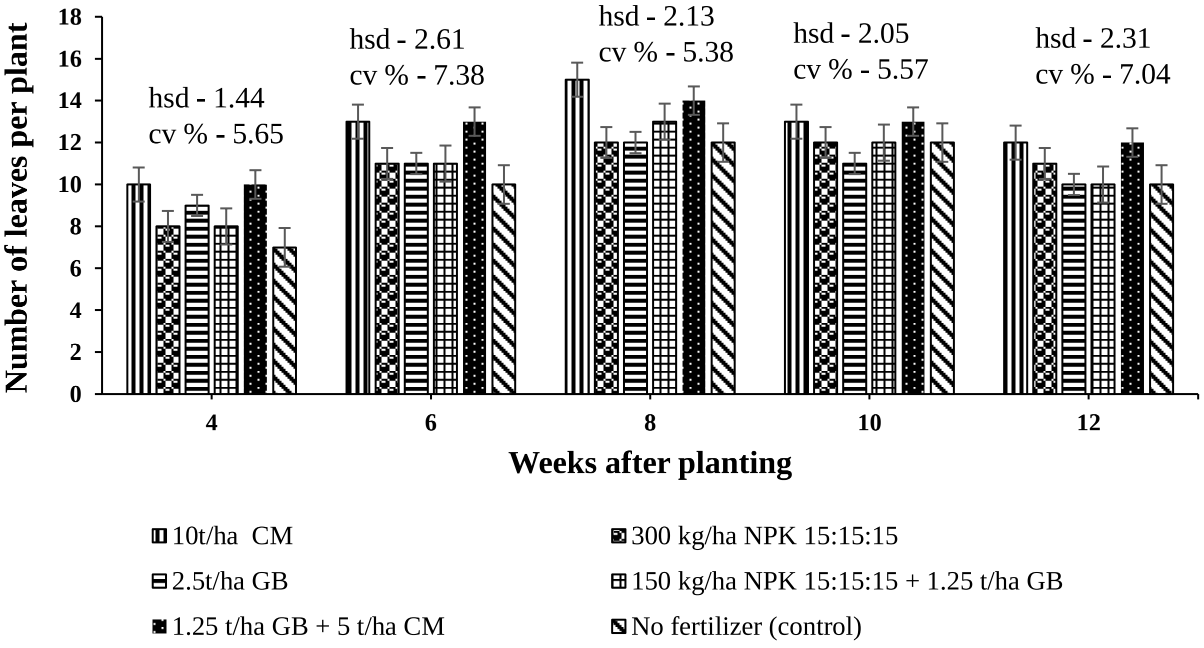
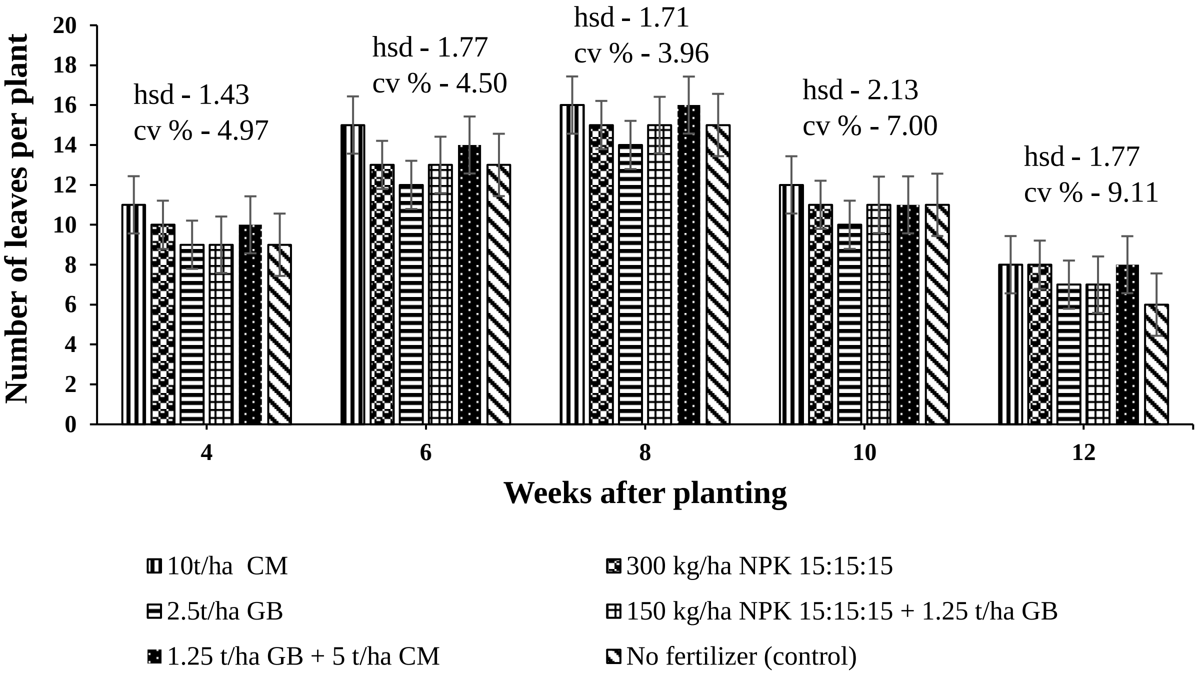


Figure 4.5: Number of leaves per plant of Omankwa maize variety as affected by biochar, chicken manure and NPK fertilizer during 2021 minor and 2022 major seasons

(a) Obatanpa, minor season



(b) Obatanpa, major season

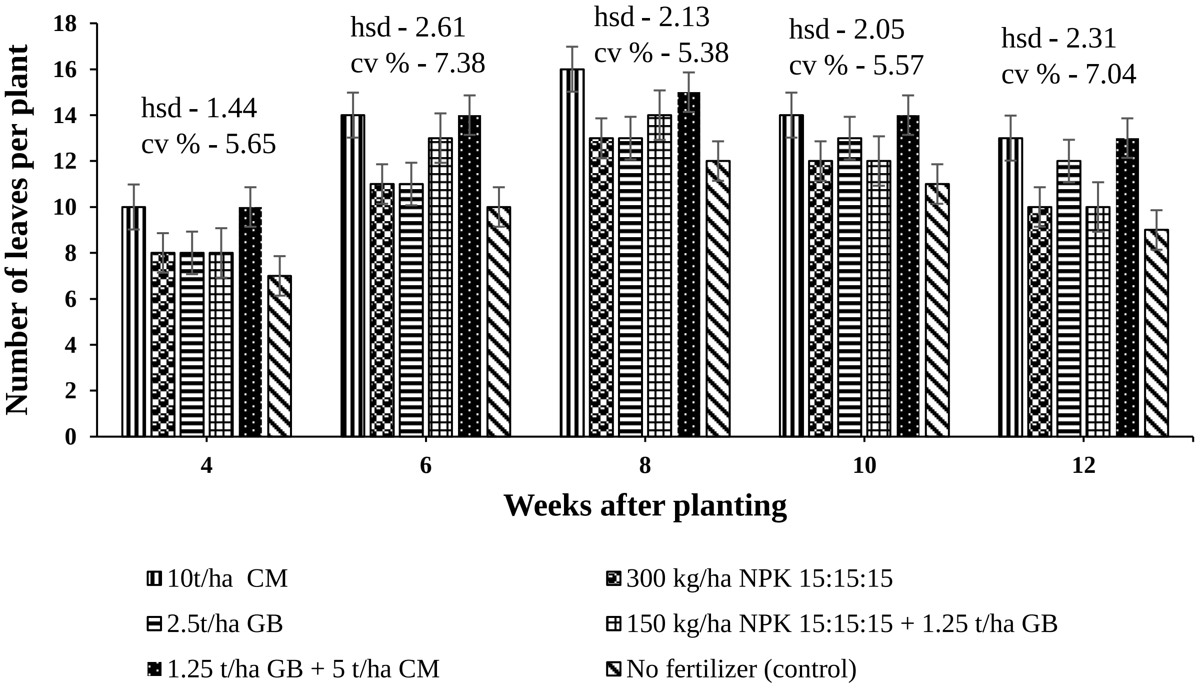


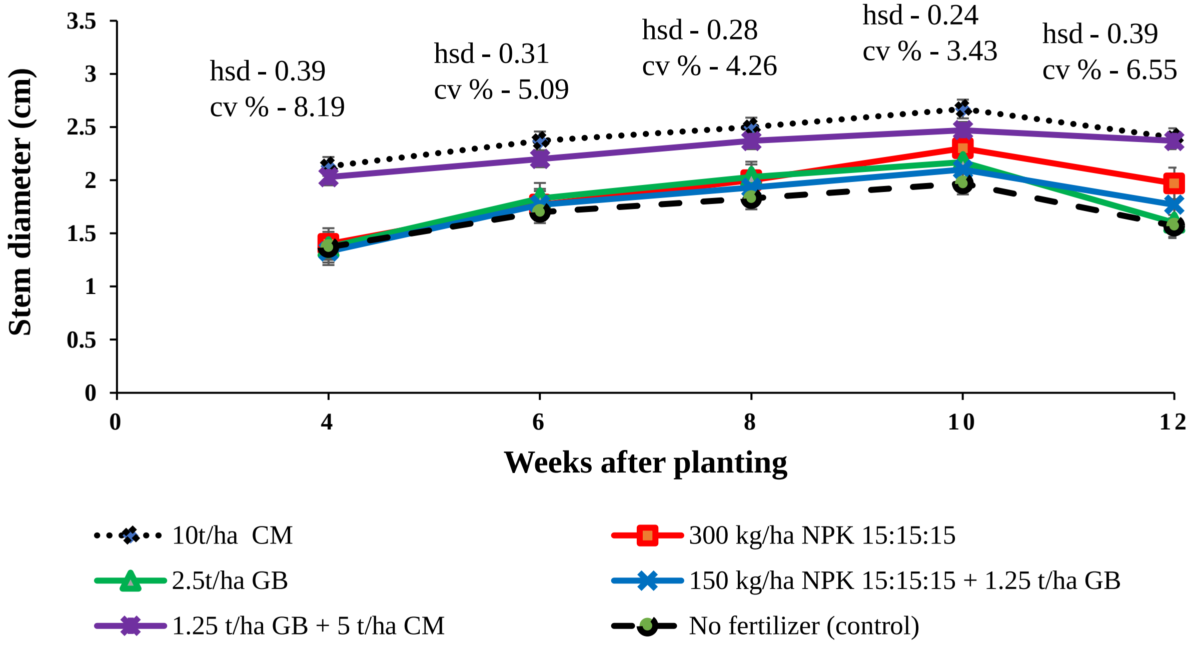
Figure 4.6: Number of leaves per plant of Obatanpa maize variety as affected by biochar, chicken manure and NPK fertilizer during 2021 minor and 2022 major seasons

4.3.4 Stem diameter

The result on stem diameter as influenced by biochar, chicken manure, and NPK fertilizer is presented in Figures 4.7 and 4.8. During the minor season (2021), application of 10 t/ha CM and 1.25 t/ha GB + 5 t/ha CM to Omankwa gave significantly ($P \leq 0.05$) wider stem diameter than the control from 4 to 12 WAP (Fig 4.7). Omankwa grown on 10 t/ha CM had the widest stem diameter that was significantly ($P \leq 0.05$) different from the other amended and control plots except 1.25 t/ha GB + 5 t/ha CM at 12 WAP. Omankwa grown on unamended plots recorded the least stem diameter from 6 to 12 WAP. (Fig 4.7). In the major season (2022), application of amendment to Omankwa differed significantly ($P \leq 0.05$) from the control in stem diameter at 6 to 12 WAP (Fig 4.7). At 4 WAP, there was no significant ($P \leq 0.05$) difference between amended and unamended plots in stem diameter. The widest stem diameter was recorded by 10 t/ha CM over the entire growing period with the lowest recorded by unamended plot during the same period (Fig 4.7).

In the minor season (2021), Obatanpa grown on amended plots differed significantly ($P \leq 0.05$) from the control plot in stem diameter from 4 to 12 WAP (Fig 4.8). Application of 10 t/ha CM to Obatanpa followed by 1.25 t/ha GB + 5 t/ha CM gave significantly wider stem diameter over the entire growing period from 4 to 12 WAP. Application of 10 t/ha CM to Obatanpa which had the widest stem diameter was significantly different from the unamended plot that recorded the least stem diameter from 4 to 12 WAP (Fig 4.8). During the 2022 major season, Obatanpa grown on amended plots differed significantly ($P \leq 0.05$) from the control in stem diameter at 4 to 12 WAP (Fig 4.8). Application of 10 t/ha CM to Obatanpa gave significantly wider stem diameter for the entire growing period whereas the least was recorded by the control plot. There was a reduction in stem diameter at 12 WAP in both seasons (Fig 4.8).

(a) Omankwa, minor season



(b) Omankwa, major season

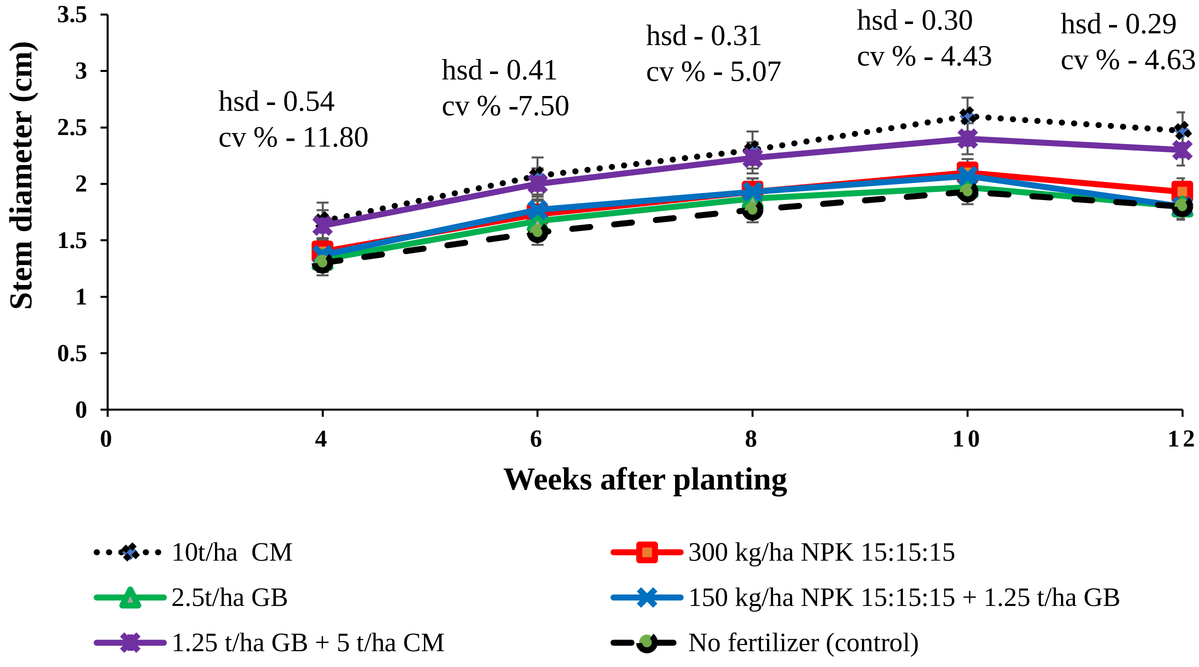
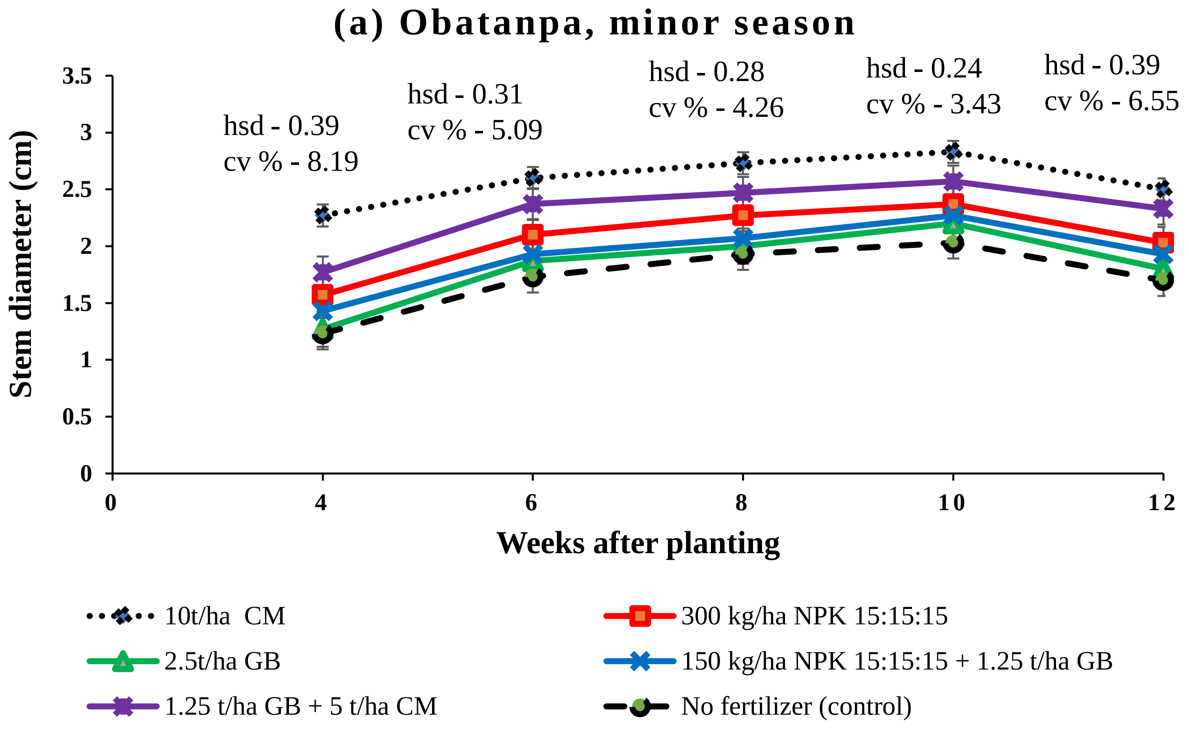


Figure 4.7: Stem diameter of Omankwa maize variety as affected by biochar, chicken manure and NPK fertilizer during 2021 minor and 2022 major seasons


(a) Obatanpa, minor season

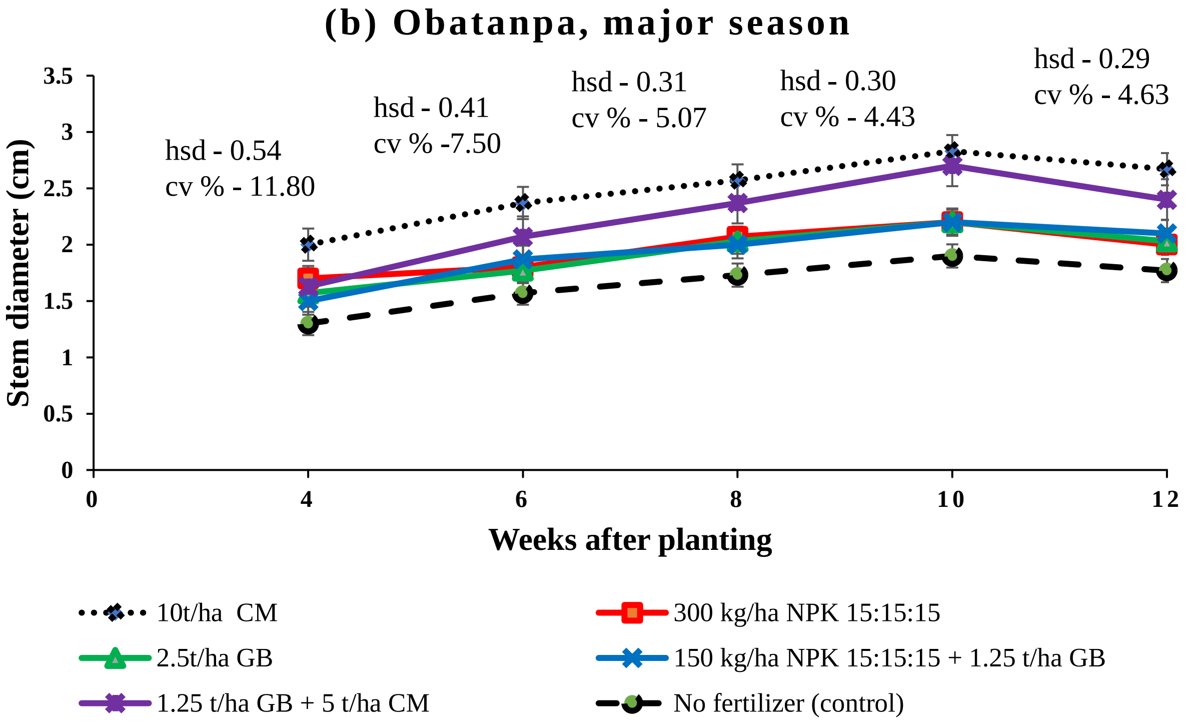

(b) Obatanpa, major season

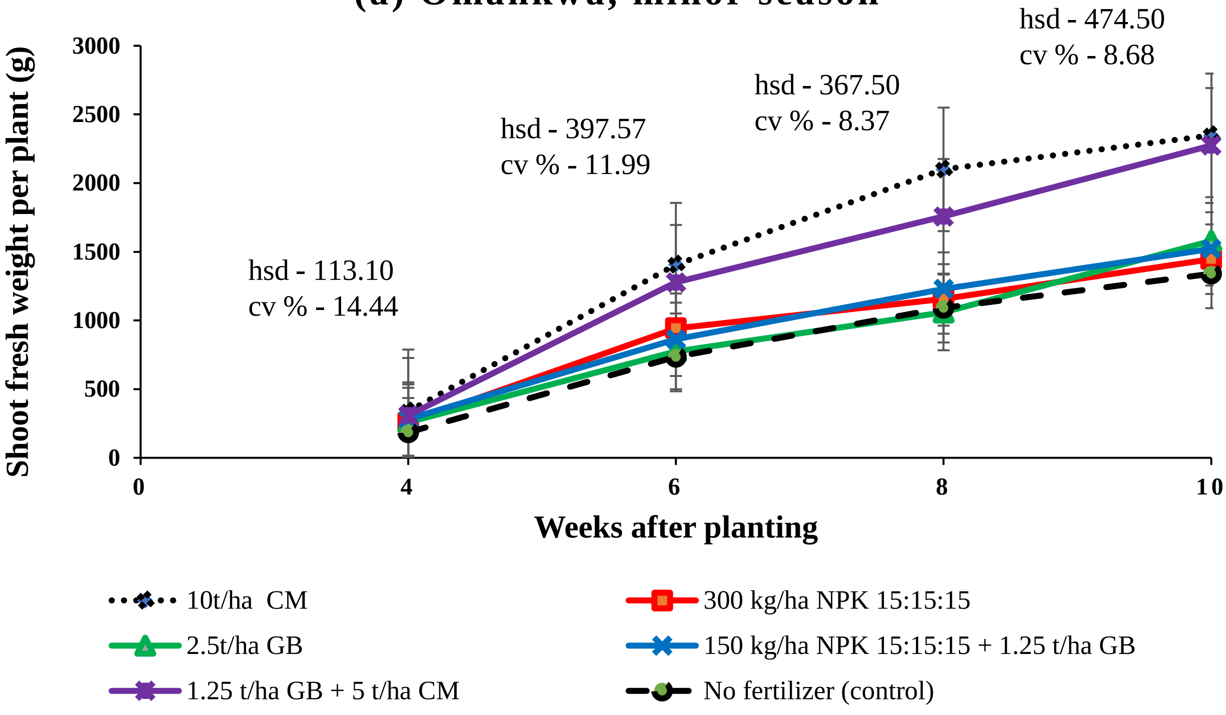
Figure 4.8: Stem diameter of Obatanpa maize variety as affected by biochar, chicken manure and NPK fertilizer during 2021 minor and 2022 major seasons

4.3.5 Shoot Fresh Weight per Plant

The result on shoot fresh weight per plant as affected by different amendments rate is presented in Figures 4.9 and 4.10. During the 2021 minor season, Omankwa grown on amended plots differed significantly ($P \leq 0.05$) from the control in shoot fresh weight per plant from 4 to 10 WAP (Fig. 4.9). At 10 WAP, application of 10 t/ha CM to Omankwa which had the highest (2347.7 g) shoot fresh weight per plant differed significantly ($P \leq 0.05$) from other amended and the control plot where the control plot recorded the lowest (1339.7 g) shoot fresh weight (Fig. 4.9). In 2022 major season, Omankwa grown on amended plots did not differ significantly ($P \geq 0.05$) from the control in shoot fresh weight per plant at 4 WAP (Fig 4.9). However, Omankwa grown on amended plots differed significantly ($P \leq 0.05$) from the control in shoot fresh weight per plant from 6 to 10 WAP. At 6 WAP, Omankwa grown on 10t/ha CM recorded the highest (1487.0 g) shoot fresh weight per plant whereas Omankwa grown on 1.25 t/ha GB + 5 t/ha CM recorded the highest (2141.0 g and 2392.0 g) shoot fresh weight with 300 kg/ha NPK treated soil recording the lowest (1063.3 g and 1264.3 g) at 8 to 10 WAP respectively (Fig. 4.9).

In 2021 minor season, Obatanpa grown on 10 t/ha CM recorded the highest shoot fresh weight per plant which differed significantly ($P \leq 0.05$) from other amended and unamended plots with the unamended plot recording the lowest shoot fresh weight at the same period (Fig. 4.10). Obatanpa grown on amended plots did not differ significantly ($P \geq 0.05$) from the control in shoot fresh weight per plant at 4 WAP during the 2022 major cropping season (Fig. 4.10). However, Obatanpa grown on amended plots differed significantly ($P \leq 0.05$) from the control in shoot fresh weight per plant from 6 to 10 WAP (Fig. 4.10). Obatanpa grown on 10 t/ha CM gave the highest shoot fresh weight per plant for the entire growing period.

(a) Omankwa, minor season



(b) Omankwa, major season

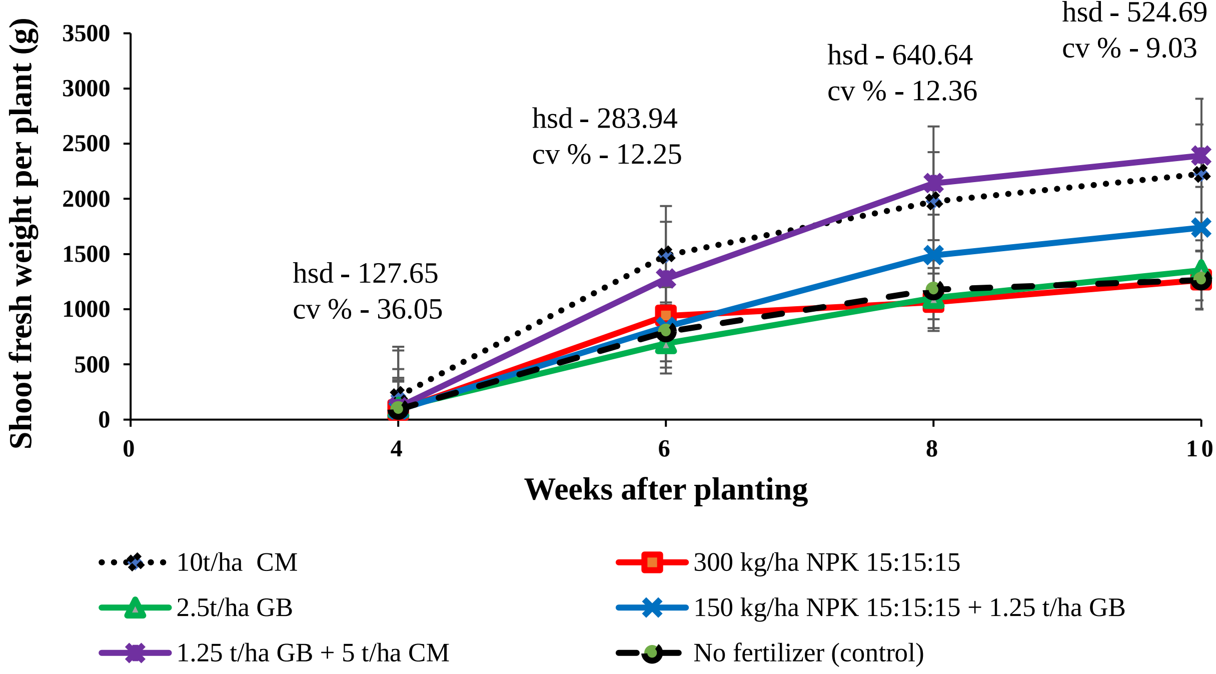
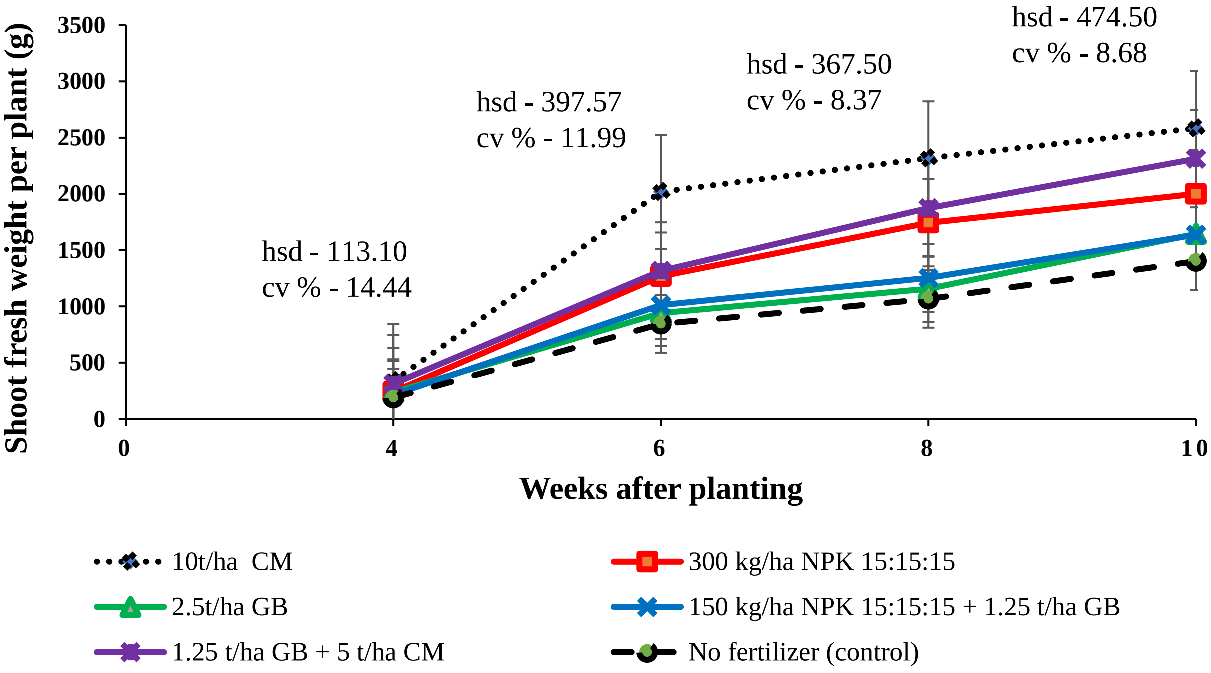
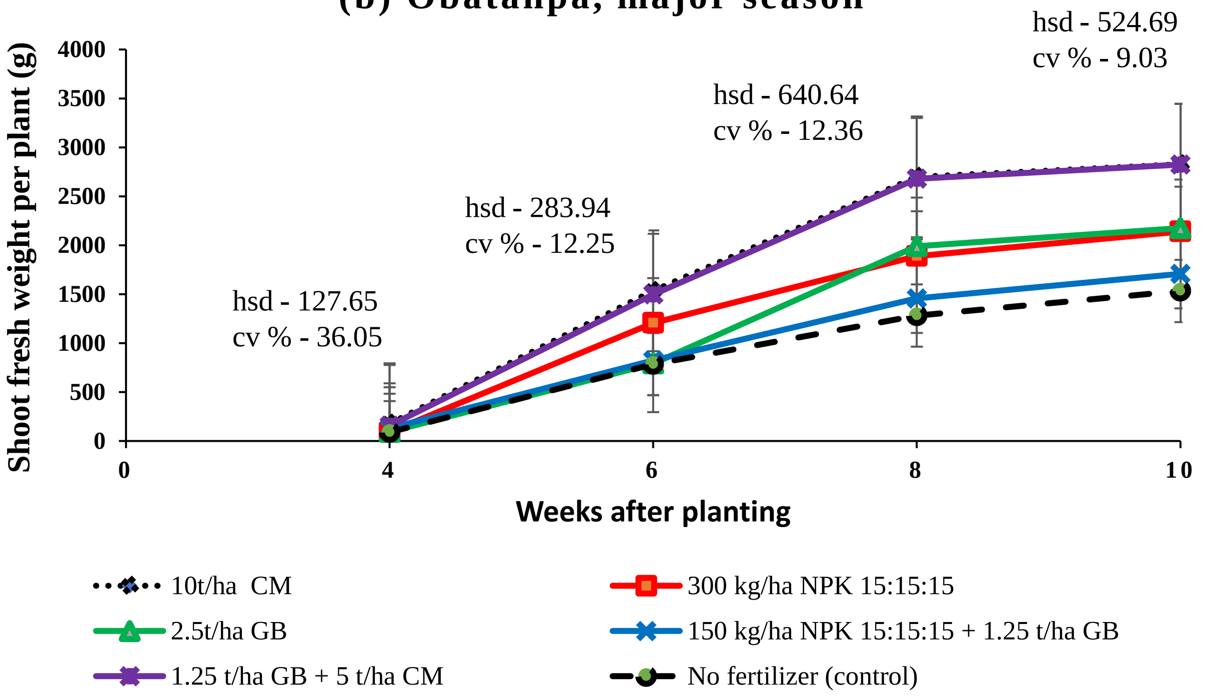


Figure 4.9: Shoot fresh weight of Omankwa maize variety as affected by biochar, chicken manure and NPK fertilizer during 2021 minor and 2022 major seasons



(a) Obatanpa, minor season



(b) Obatanpa, major season

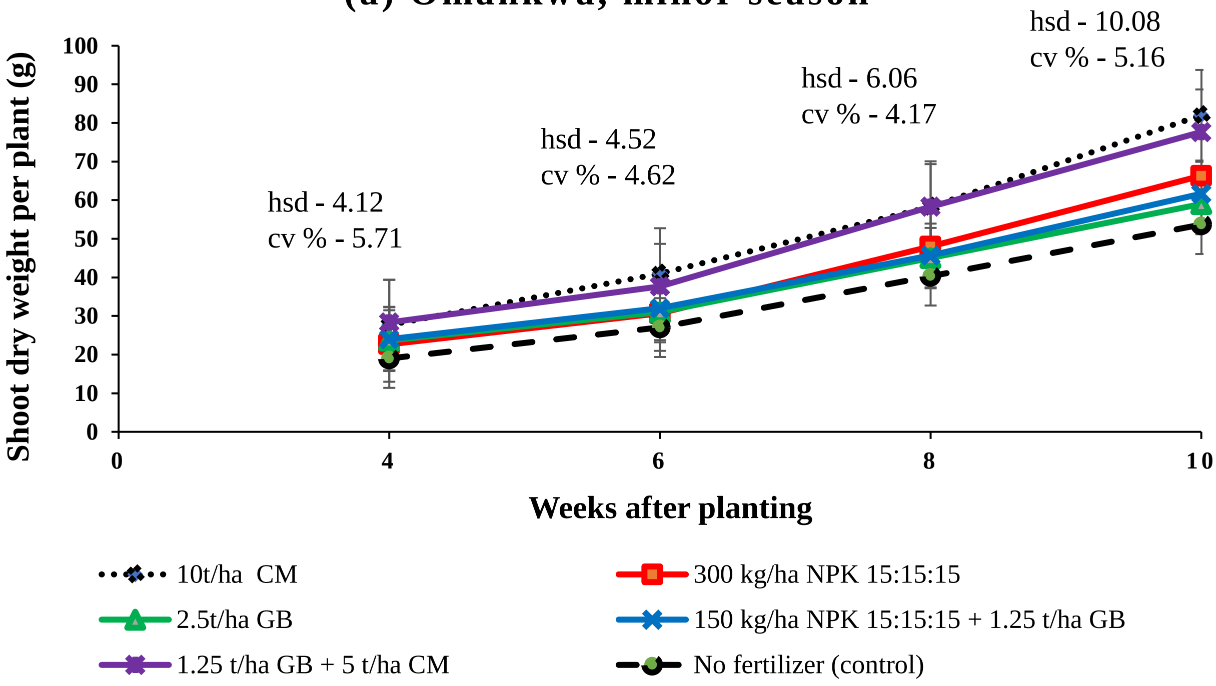
Figure 4.10: Shoot fresh weight of Obatanpa maize variety as affected by biochar, chicken manure and NPK fertilizer during 2021 minor and 2022 major seasons

4.3.6 Shoot Dry Weight per Plant

The result on shoot dry weight per plant as influenced by different amendment rates is presented in Figures 4.11 and 4.12. During the 2021 minor season, Omankwa grown on amended plots differed significantly ($P \leq 0.05$) from the control in shoot dry weight per plant from 4 to 10 WAP (Fig. 4.11). Application of 10 t/ha CM to Omankwa which had the highest (82.0 g) shoot dry weight per plant differed significantly ($P \leq 0.05$) from other amended and the control plots at 10 WAP. The least (53.67 g) shoot dry weight per plant was recorded by the control plot at 10 WAP (Fig. 4.11). In 2022 major season, Omankwa grown on amended plots did not differ significantly ($P \geq 0.05$) from the control plot in shoot dry weight per plant at 4 WAP, 6 WAP, and 10 WAP (Fig 4.11). Application of 10 t/ha CM to Omankwa which had the highest (47.33 g) shoot dry weight per plant differed significantly ($P \leq 0.05$) from the control plot at 8 WAP with the least (28.00 g) shoot dry weight per plant recorded by the control plot (Fig. 4.11).

In 2021 minor season, Obatanpa grown on amended plots differed significantly ($P \leq 0.05$) from the control plot in shoot dry weight per plant from 4 to 10 WAP (Fig. 4.12). Application of 10 t/ha CM to Obatanpa which had the highest (83.0 g) shoot dry weight per plant differed significantly ($P \leq 0.05$) from other amended and the control plots at 10 WAP whereas the control plot gave the lowest (51.67 g) shoot dry weight per plant at the same period (Fig 4.12). There was no significant ($P \geq 0.05$) difference between Obatanpa grown on amended and unamended plots in shoot dry weight from 4 to 10 WAP during 2022 major season (Fig. 4.12).

(a) Omankwa, minor season



(b) Omankwa, major season

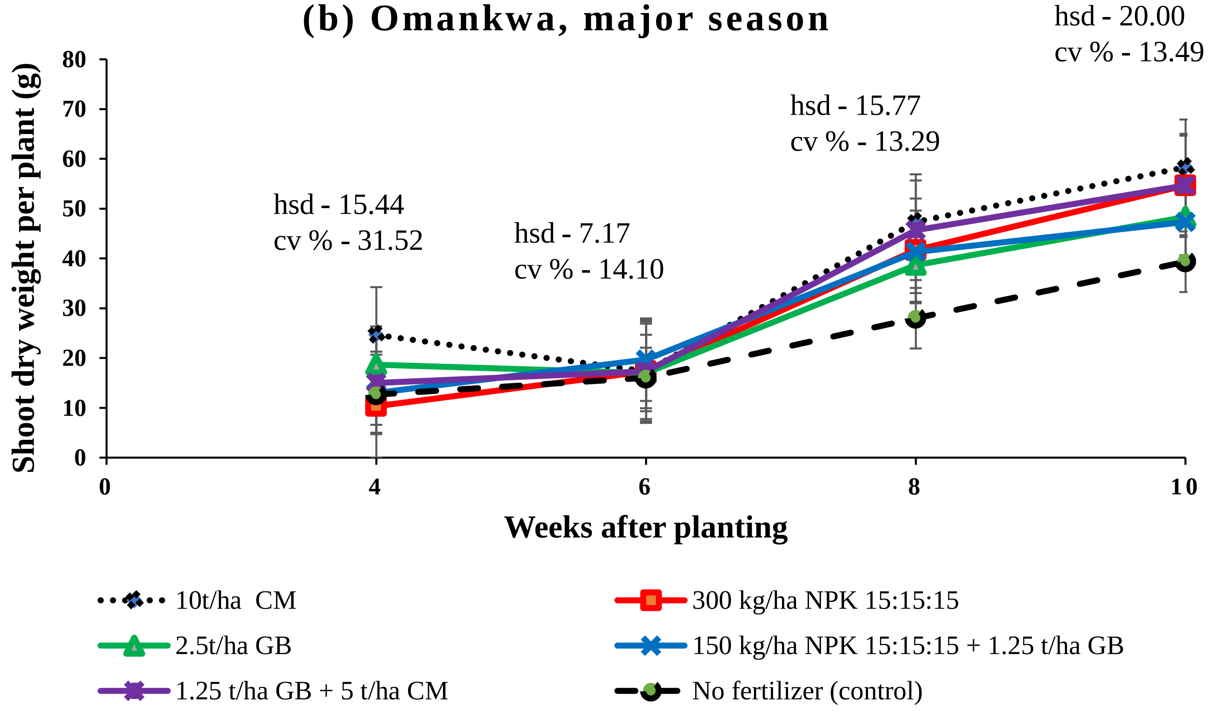
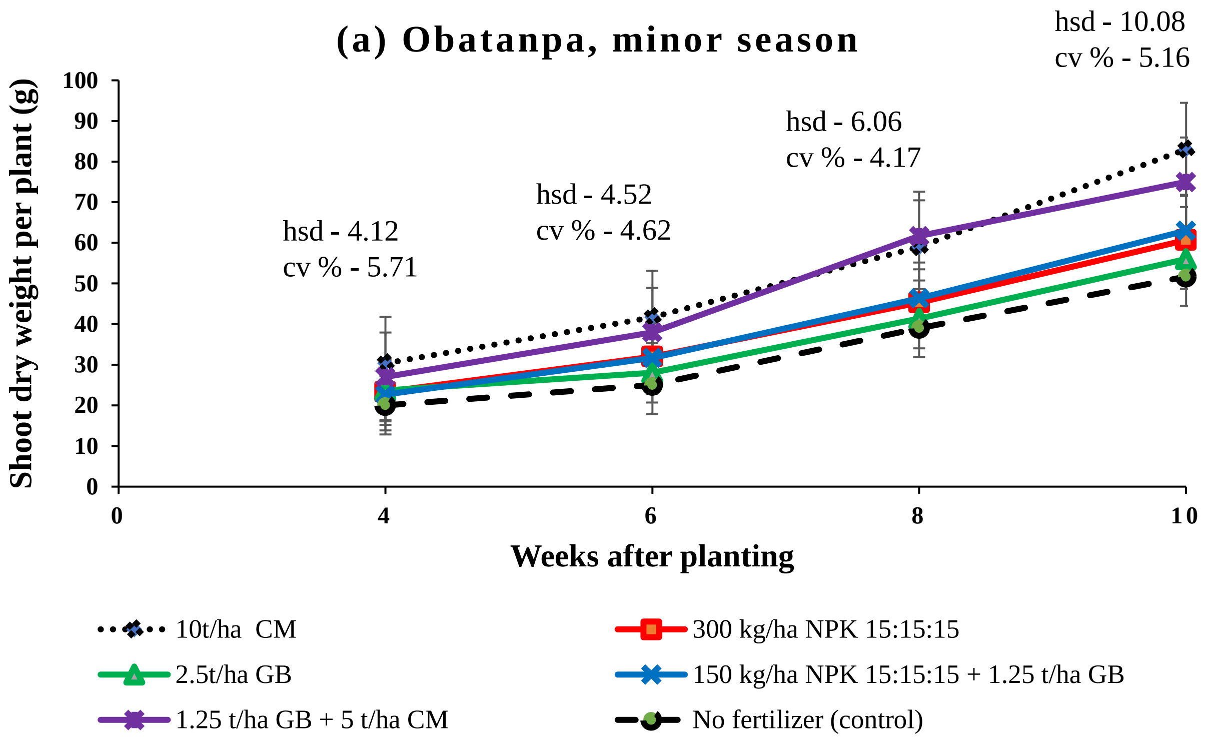


Figure 4.11: Shoot dry weight of Omankwa maize variety as affected by biochar, chicken manure and NPK fertilizer during 2021 minor and 2022 major seasons



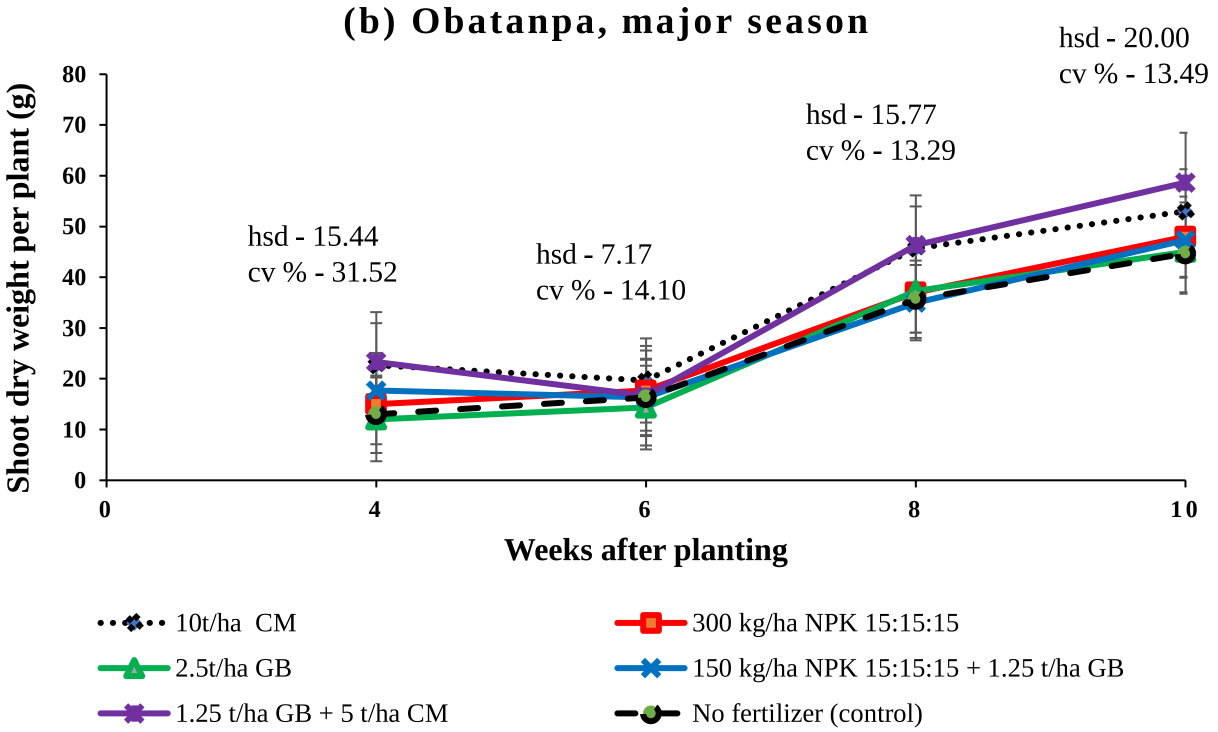
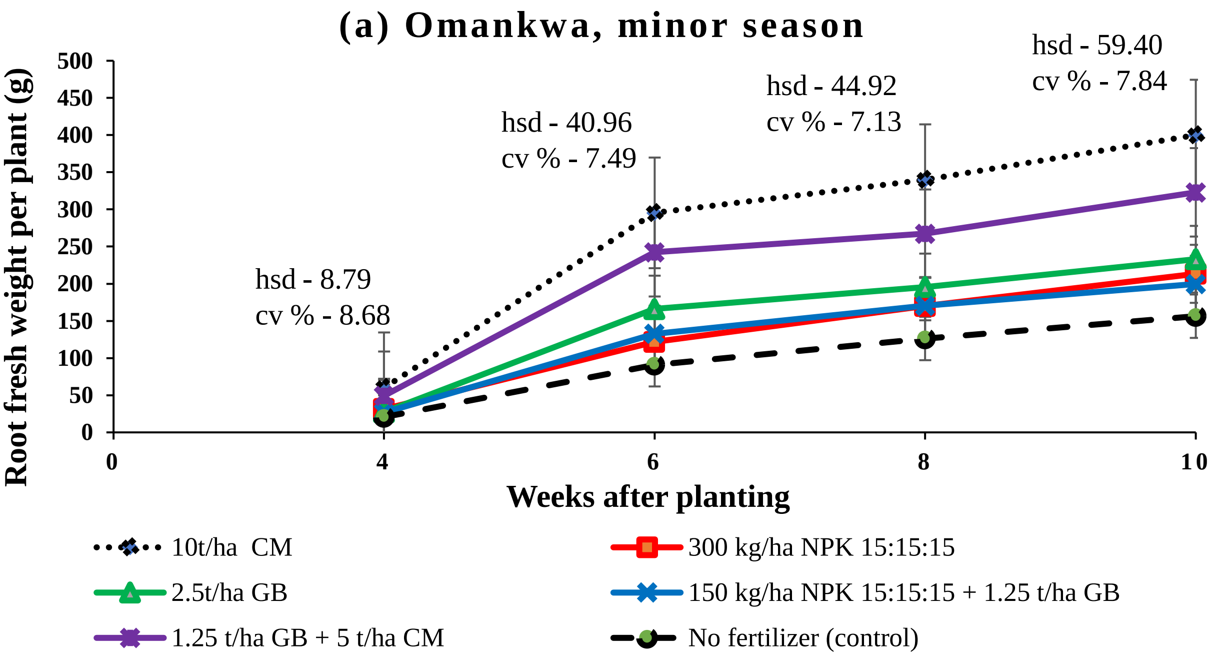


Figure 4.12: Shoot dry weight of Obatanpa maize variety as affected by biochar, chicken manure and NPK fertilizer during 2021 minor and 2022 major seasons

4.3.7 Root Fresh Weight per Plant

The result on root fresh weight per plant as influenced by biochar, chicken manure, and NPK fertilizer is presented in Figures 4.13 and 4.14. During the 2021 minor season, Omankwa grown on amended plots differed significantly ($P \leq 0.05$) from the control plot in root fresh weight per plant from 4 to 10 WAP (Fig. 4.13). Omankwa grown on 10 t/ha CM treated plot recorded the highest root fresh weight throughout the entire growing period whereas the unamended plot recorded the least root fresh weight during the same period (Fig. 4.13). In 2022 major season, Omankwa grown on amended plots did not differ significantly ($P \geq 0.05$) from the control plot in root fresh weight per plant at 4 WAP (Fig 4.13). However, Omankwa grown on amended plots differed significantly ($P \leq 0.05$) from the control plot in root fresh weight per plant from 6 to 10 WAP. The highest root fresh weight per plant was recorded by 10 t/ha CM over the entire growing period with unamended plots recording the least root fresh weight during the same period (Fig 4.13).

Obatanpa grown on amended plots differed significantly ($P \leq 0.05$) from the control plot in root fresh weight per plant from 4 to 10 WAP during 2021 minor season (Fig 4.14). Application of 10 t/ha CM to Obatanpa had significantly higher root fresh weight per plant for the entire period whereas the unamended plot recorded the least root fresh weight at the same period (Fig 4.14). In 2022 major season, Obatanpa grown on amended plots did not differ significantly ($P \geq 0.05$) from the control in root fresh weight per plant from 4 to 6 WAP (Fig 4.14). However, Obatanpa grown on amended plots differed significantly ($P \leq 0.05$) from the control in root fresh weight per plant from 8 to 10 WAP (Fig. 4.14). Application of 10 t/ha CM to Obatanpa had significantly higher root fresh weight per plant for the entire growing period. The lowest root fresh weight per plant over the period was recorded by control plots (Fig 4.14).


(a) Omankwa, minor season

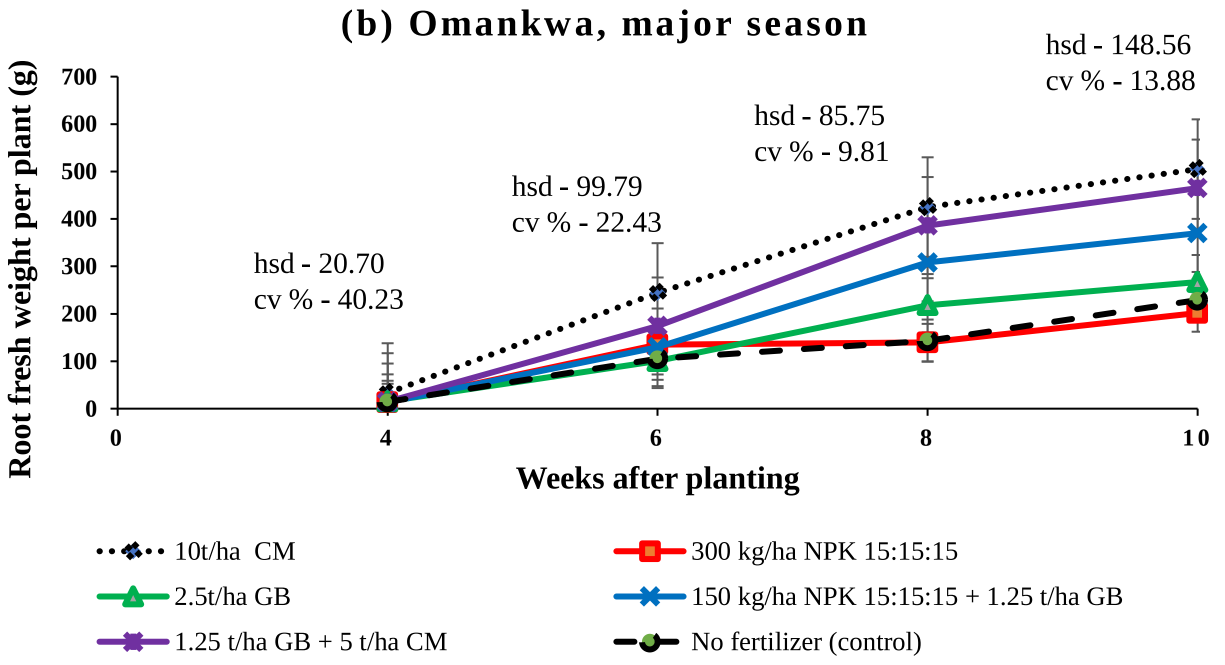
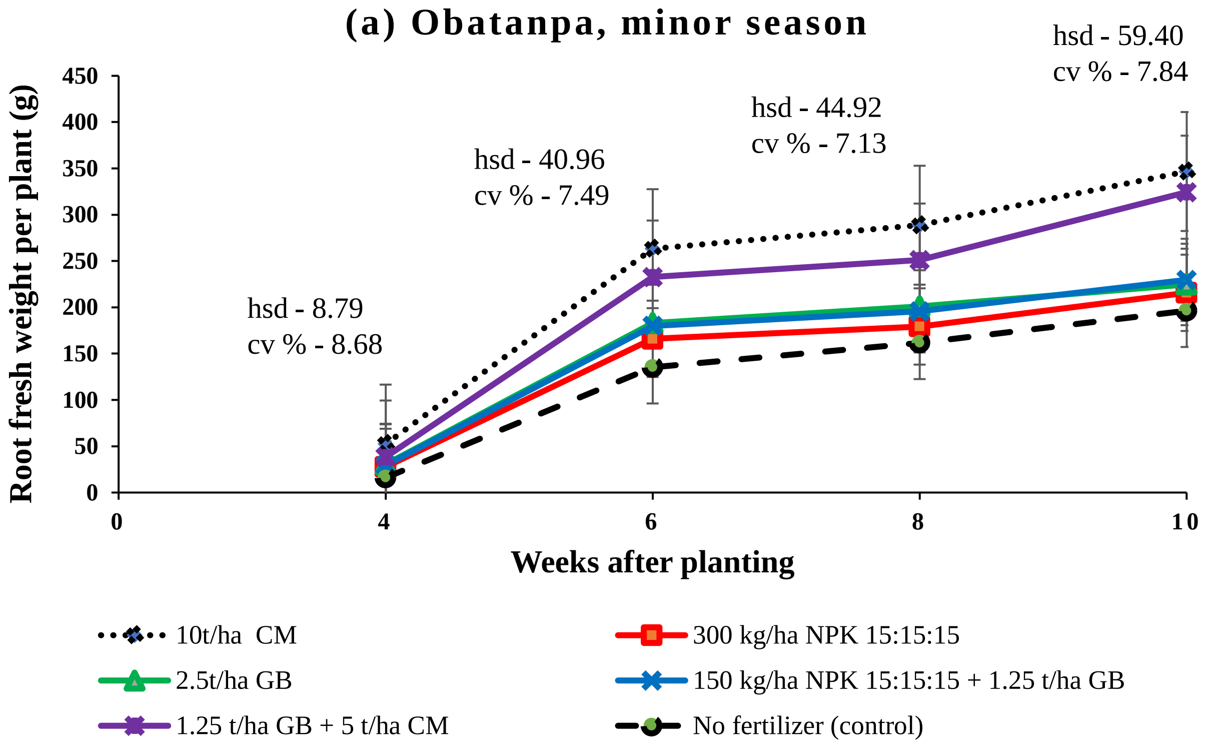

(b) Omankwa, major season

Figure 4.13: Root fresh weight of Omankwa maize variety as affected by biochar, chicken manure and NPK fertilizer during 2021 minor and 2022 major seasons



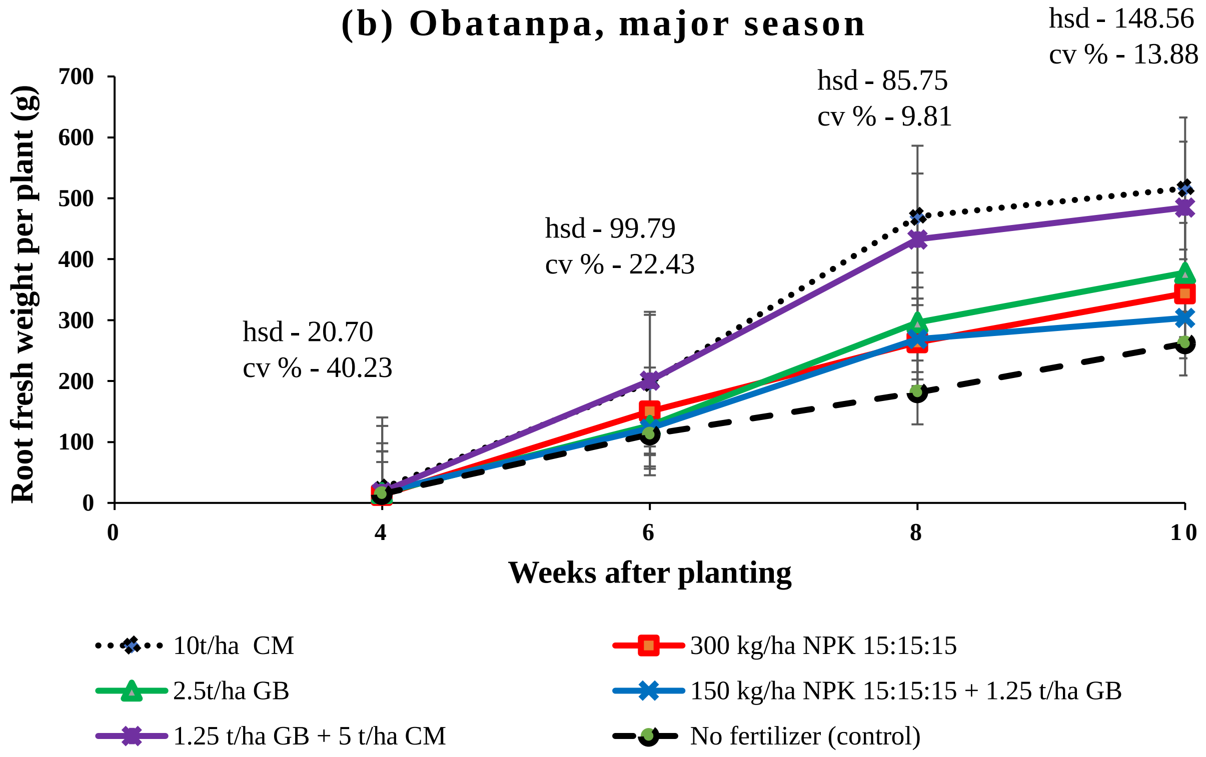


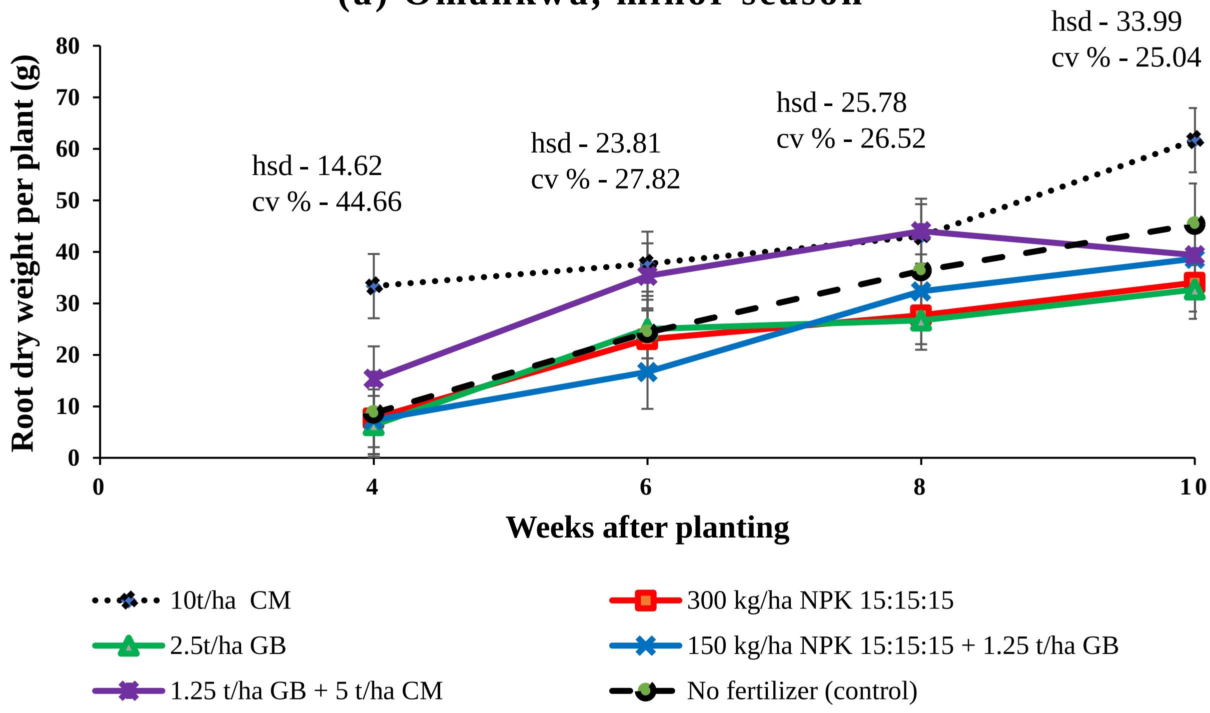
Figure 4.14: Root fresh weight of Obatanpa maize variety as affected by biochar, chicken manure and NPK fertilizer during 2021 minor and 2022 major seasons

4.3.8 Root Dry Weight per Plant

The result on root dry weight per plant as influenced by biochar, chicken manure, and NPK fertilizer is presented in Figures 4.15 and 4.16. During the 2021 minor season, Omankwa grown on amended plots differed significantly (P≤0.05) from the control in root dry weight per plant at 4 WAP (Fig 4.15). At 4 WAP, Omankwa grown on 10 t/ha CM gave the highest (33.33 g) root dry weight with 2.5 t/ha GB treated plot recording the least (6.33 g). Omankwa grown on amended plots did not differ significantly (P≥0.05) from the control plot in root dry weight per plant from 6 to 10 WAP (Fig 4.15). In the major season (2022), Omankwa grown on amended plots did not differ significantly (P≥0.05) from the control plot in root dry weight per plant from 4 to 10 WAP (Fig 4.15). Omankwa grown on amended plots differed significantly (P≤0.05) from the control in root dry weight per plant at 8 WAP. Application of 10 t/ha CM to Omankwa had the highest (67.33 g) root dry weight per plant whereas the lowest (48.33 g) was recorded by the control plot (Fig 4.15).

In the minor season (2021), Obatanpa grown on amended plots did not differ significantly (P≥0.05) from the control plot in root dry weight per plant for the entire growing period (Fig. 4.16). During the 2022 major season, Obatanpa grown on amended plots did not differ significantly (P≥0.05) from the control plot in root dry weight per plant from 4 to 6 WAP (Fig 4.16). Obatanpa grown on amended plots differed significantly (P≤0.05) from the control plot in root dry weight per plant from 8 to 10 WAP (Fig. 4.16). Application of 1.25 t/ha GB + 5 t/ha CM and 10 t/ha CM to Obatanpa which had the highest (86.67 g) root dry weight per plant differed significantly (P≤0.05) from other amended and the control plot at 10 WAP with the unamended plot recording the least (62.0 g) root dry weight per plant at the same period (Fig 4.16).

(a) Omankwa, minor season



(b) Omankwa, major season

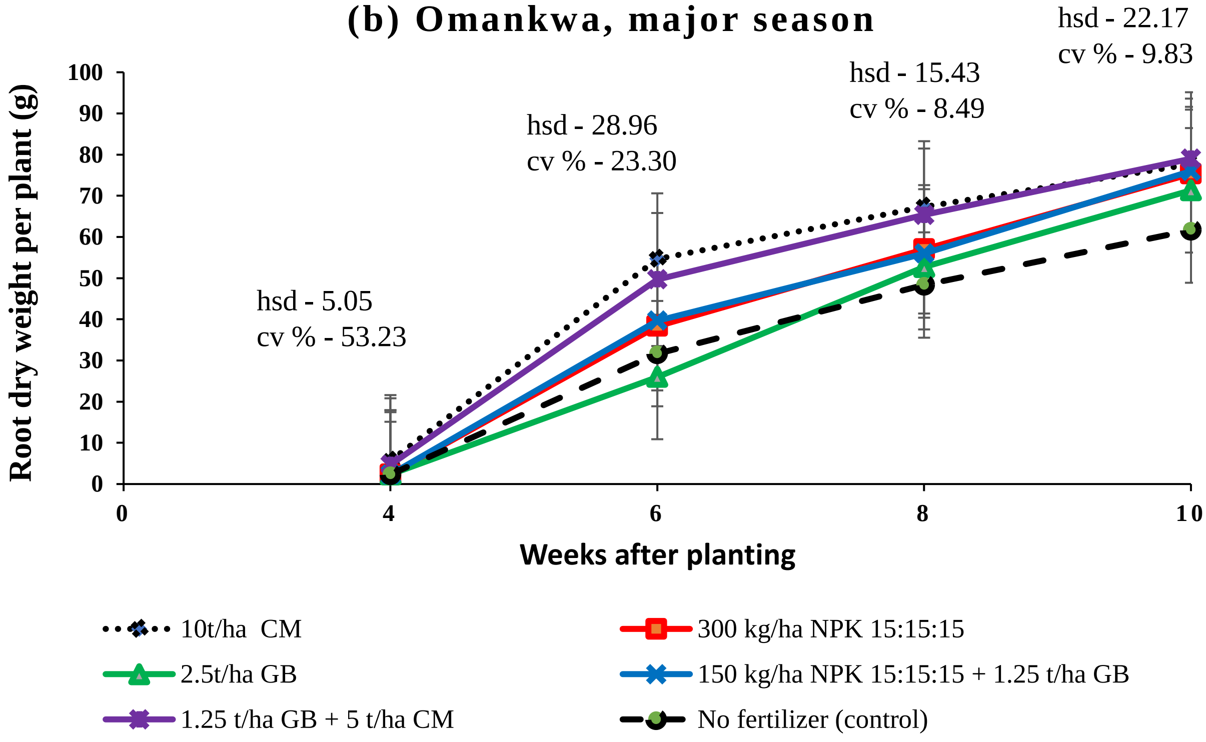
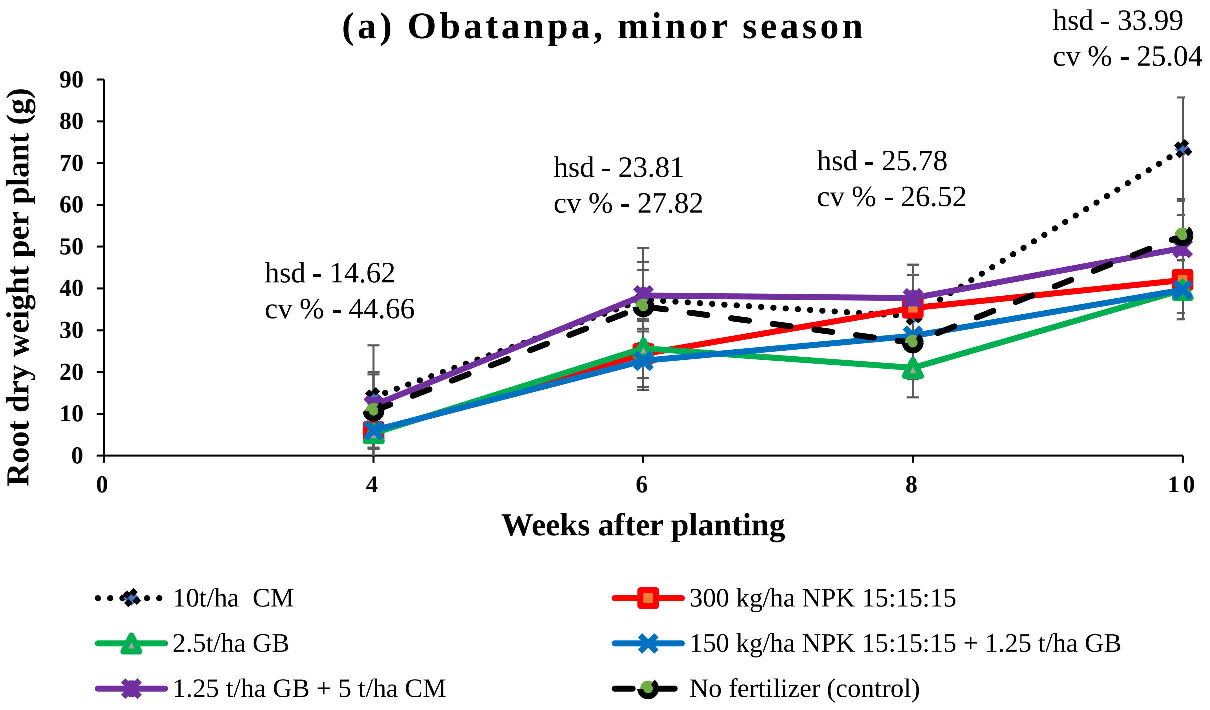


Figure 4.15: Root dry weight of Omankwa maize variety as affected by biochar, chicken manure and NPK fertilizer during 2021 minor and 2022 major seasons



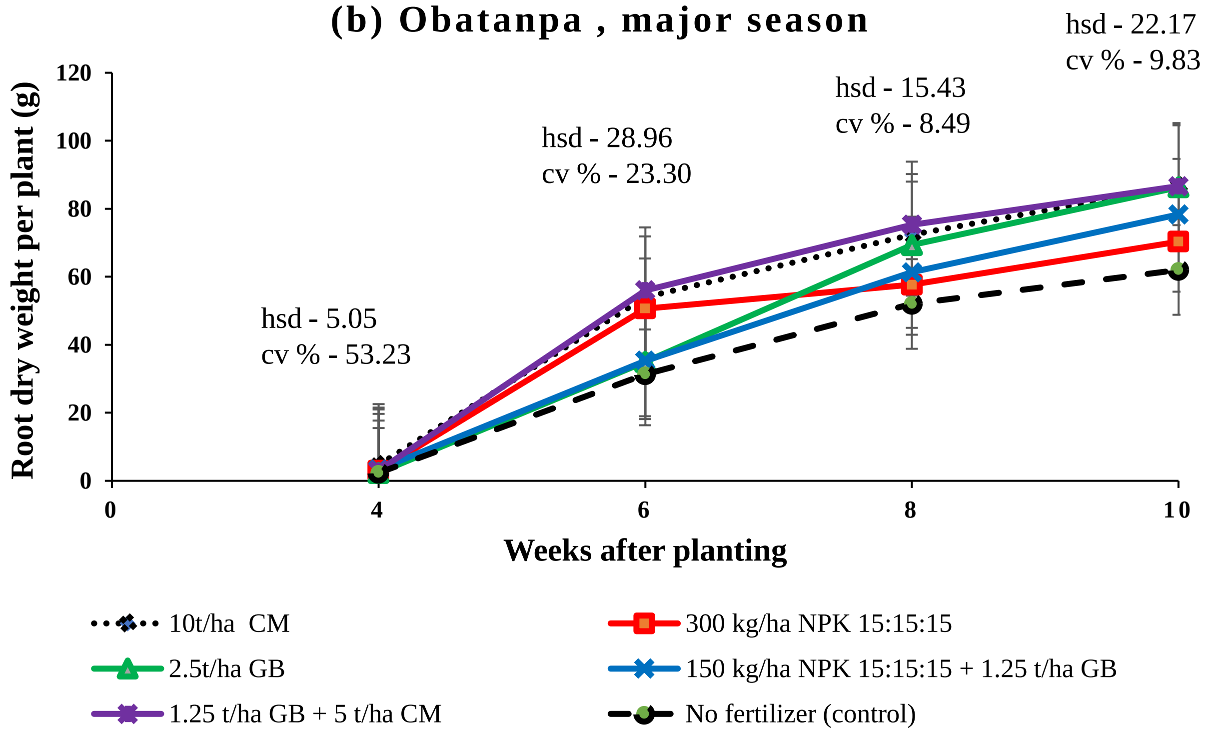


Figure 4.16: Root dry weight of Obatanpa maize variety as affected by biochar, chicken manure and NPK fertilizer during 2021 minor and 2022 major seasons

4.4 Yield and Yield Components

4.4.1 Number of plants harvested

Table 4.5 shows the number of plants harvested as influenced by biochar, chicken manure, and NPK fertilizer. During the 2021 minor season, there was no significant ($P \geq 0.05$) difference between Omankwa and Obatanpa in number of plants harvested. For the individual effect of fertilizer rates on number of plants harvested, 10 t/ha CM recorded the highest (39.00) number of plants harvested that was not significantly ($P \geq 0.05$) different from other amended plots but significantly ($P \leq 0.05$) different from the unamended plot with the least (36.00) mean value. Omankwa x 150 kg/ha NPK + 1.25 t/ha GB interaction had the highest number of plants harvested (39.33) that was significantly ($P \leq 0.05$) different from the control plot which recorded the least (35.00) number of plants harvested. No significant ($P \geq 0.05$) difference was observed between Obatanpa x amended and unamended plots interaction in number of plants harvested (Table 4.5).

In the 2022 major season, biochar, chicken manure, and NPK fertilizer applied either singly or in combination did not significantly ($P \geq 0.05$) influence number of plants harvested for the two maize varieties. In both seasons, Omankwa x unamended plot interaction had the least (35.00) number of harvested plants. There was no significant ($P \geq 0.05$) difference between season and season x variety x fertilizer rates (Table 4.5).

4.4.2 Number of Cobs per Plant

Table 4.5 shows number of cobs per plant as influenced by biochar, chicken manure, and NPK fertilizer. During the minor season (2021), biochar, chicken manure, and inorganic fertilizer applied either singly or in combination did not significantly influence the number of cobs per plant for the two maize varieties (Table 4.5).

In the major season (2022), there was no significant ($P \geq 0.05$) difference between Omankwa and Obatanpa in number of cobs per plant. For the individual effect of fertilizer rates on number of cobs per plant, significant ($P \leq 0.05$) difference occurred between treatments. The amended and unamended plots except for 150 kg/ha NPK + 1.25 t/ha GB were significantly ($P \leq 0.05$) different from 2.5 t/ha GB which recorded the least (1.33) number of cobs per plant. No significant ($P \geq 0.05$) difference occurred in variety x fertilizer interaction in number of cobs per plant (Table 4.5).

There was no significant ($P \geq 0.05$) difference between season and season x variety x fertilizer rates (Table 4.5).

Table 4.5: Number of plants harvested and Number of cobs per plant as affected by biochar, chicken manure and NPK fertilizer during 2021 Minor and 2022 Major Seasons

Treatment	Number of plants harvested		Number of cobs per plant	
	2021 minor season	2022 major season	2021 minor season	2022 major season
Variety				
Omankwa	38.33	37.50	1.94	1.83
Obatanpa	37.83	37.17	1.78	0.83
HSD (P ≤ 0.05)	**NS**	**NS**	**NS**	**NS**
Fertilizer rates				
10 t/ha CM	39.00a	38.00	2.00	2.00a
300 kg/ha NPK 15:15:15	38.17ab	37.67	2.00	2.00a
2.5 t/ha GB	38.50a	36.83	1.50	1.33b
150 kg/ha NPK + 1.25 t/ha GB	38.67a	37.17	1.67	1.67ab
1.25 t/ha GB + 5 t/ha CM	38.17ab	37.50	2.00	2.00a
No fertilizer (Control)	36.00b	36.83	2.00	2.00a
HSD (P ≤ 0.05)	**2.43**	**NS**	**NS**	**0.63**
Interaction (V X F)				
Omank. **x** 10 t/ha CM	39.00ab	37.33	2.00	2.00
Omank. **x** 300 kg/ha NPK 15:15:15	38.67ab	38.67	2.00	2.00
Omank. **x** 2.5 t/ha GB	39.00ab	38.67	1.67	1.67
Omank. **x** 150 kg/ha NPK + 1.25 t/ha GB	39.33a	37.33	2.00	1.67
Omank. **x** 1.25 t/ha GB + 5 t/ha CM	39.00ab	37.67	2.00	2.00
Omank. **x** No fertilizer (Control)	35.0b	35.33	2.00	1.33
Obatan. **x** 10 t/ha CM	39.00ab	38.67	2.00	2.00
Obatan. **x** 300 kg/ha NPK 15:15:15	37.67ab	36.67	2.00	2.00
Obatan. **x** 2.5 t/ha GB	38.00ab	35.00	1.33	2.00
Obatan. **x** 150 kg/ha NPK + 1.25 t/ha GB	38.00ab	37.00	1.33	2.00
Obatan. **x** 1.25 t/ha GB + 5 t/ha CM	37.33ab	37.33	2.00	2.00
Obatan. **x** No fertilizer (Control)	37.00ab	38.33	2.00	1.33
HSD (P ≤ 0.05)	**4.00**	**NS**	**NS**	**NS**
CV (%)	**3.54**	**4.80**	**15.27**	**18.99**

x – interaction CM – Chicken manure GB – *Gliricidia sepium* biochar

Variety (V)	= NS	NS
Fertilizer rates (Fr.)	= NS	NS
Season (S)	= NS	NS
S x V	= NS	NS
Fr. x V	= 3.21**	NS
Fr. x S	= NS	0.62**
S x Fr. x V	= NS	NS

4.4.3 Cob Length

Table 4.6 shows cob length as influenced by biochar, chicken manure, and NPK fertilizer. During the minor season (2021), there was no significant ($P \geq 0.05$) difference between Omankwa and Obatanpa in cob length. For the individual effect of fertilizer rates on cob length, 10 t/ha CM plot recorded the longest (15.51 cm) cob length that was significantly ($P \leq 0.05$) different from the unamended plot which recorded the shortest (12.98 cm). There was no significant ($P \geq 0.05$) difference between variety x fertilizer interaction on cob length for the two maize varieties (Table 4.6).

In the major season (2022), there was a significant ($P \leq 0.05$) difference between Obatanpa and Omankwa in cob length. Obatanpa recorded significantly ($P \leq 0.05$) longer (17.72 cm) cob length than Omankwa which recorded the least (16.55 cm) (Table 4.6). For the fertilizer rates, 1.25 t/ha GB + 5 t/ha CM had significantly ($P \leq 0.05$) longer cob length than 2.5 t/ha GB and the control (Table 4.6). There was a significant ($P \leq 0.05$) difference between Omankwa grown on amended and unamended plots interaction in cob length. Omankwa x 1.25 t/ha GB + 5 t/ha CM interaction recorded significantly ($P \leq 0.05$) longer (18.07 cm) cob length than 2.5 t/ha GB treated plot (15.49 cm). Obatanpa x 10 t/ha CM interaction plot produced significantly ($P \leq 0.05$) longer (19.21 cm) cob than the control plot (16.13 cm). Obatanpa x amended and control plots interaction during the major season produced substantially longer cob length than Omankwa grown on the same treatments. Both maize varieties grown on amended and unamended plots during the 2022 major season had higher cob lengths than lengths obtained during the 2021 minor season. There was a significant ($P \leq 0.05$) difference between seasons with cob length in the major season (2022) being significantly longer than the lengths recorded in the minor season (2021) (Table 4.6). No significant ($P \geq 0.05$) difference occurred between season x variety x fertilizer rates interactions.

4.4.4 Cob Diameter

Table 4.6 shows cob diameter as influenced by biochar, chicken manure, and NPK fertilizer. During the 2021 minor season, there was no significant ($P \geq 0.05$) difference between Omankwa and Obatanpa in cob diameter. For individual effect of fertilizer rates on cob diameter, 10 t/ha CM plot recorded the widest (4.56 cm) cob diameter that was significantly ($P \leq 0.05$) different from the unamended plot which recorded the least (4.03 cm). There was no significant ($P \geq 0.05$) difference between Omankwa x amended and unamended plots interactions in cob diameter although differences exist between treatments. Obatanpa x 10 t/ha CM interaction recorded significantly ($P \leq 0.05$) wider cod diameter than the control plot (3.99 cm).

In the major season (2022), there was a significant ($P \leq 0.05$) difference between Omankwa and Obatanpa in cob diameter. Obatanpa recorded significantly ($P \leq 0.05$) wider (5.07 cm) cob diameter than Omankwa which recorded the least (4.79 cm) (Table 4.6). 10 t/ha CM had the widest (5.21 cm) cob diameter that was significantly ($P \leq 0.05$) different from the unamended plot which recorded the least (4.70 cm). There was no significant ($P \geq 0.05$) difference between Omankwa x amended and unamended plots interactions in cob diameter although differences exist between treatments. Obatanpa x 10 t/ha CM interaction produced significantly ($P \leq 0.05$) wider (5.45 cm) cob diameter than the unamended plot (4.71 cm). Generally, Obatanpa x amended plots interaction in the 2021 minor and 2022 major seasons produced substantially higher cob diameter than Omankwa grown on the same treatments (Table 4.6).

There was a significant ($P \leq 0.05$) difference between seasons (Table 4.6). Both maize varieties (Omankwa and Obatanpa) x amended and unamended plots interaction in the 2022 major season had wider cob diameter than diameters obtained during the 2021 minor season. No significant ($P \geq 0.05$) difference occurred between season x variety x fertilizer rates interactions.

Table 4.6: Cob Length and Cob Diameter as affected by biochar, chicken manure and NPK fertilizer during 2021 Minor and 2022 Major Seasons

Treatment	Cob length (cm)		Cob diameter (cm)	
	2021 minor season	2022 major season	2021 minor season	2022 major season
Variety				
Omankwa	13.84	16.55b	4.18	4.79b
Obatanpa	14.30	17.72a	4.32	5.07a
HSD (P ≤ 0.05)	**NS**	**0.67**	**NS**	**0.11**
Fertilizer rates				
10 t/ha CM	15.51a	18.28ab	4.56a	5.21a
300 kg/ha NPK 15:15:15	13.47bc	16.64bc	4.19ab	4.87b
2.5 t/ha GB	13.58bc	16.51c	4.05b	4.79b
150 kg/ha NPK + 1.25 t/ha GB	13.91abc	16.84abc	4.13b	4.83b
1.25 t/ha GB + 5 t/ha CM	14.97ab	18.49a	4.52a	5.18a
No fertilizer (Control)	12.98c	16.05c	4.03b	4.70b
HSD (P ≤ 0.05)	**1.93**	**1.74**	**0.39**	**0.29**
Interaction (V X F)				
Omank. **x** 10 t/ha CM	15.47	17.35abc	4.45ab	4.96bc
Omank. **x** 300 kg/ha NPK 15:15:15	12.85	15.94c	4.04ab	4.66c
Omank. **x** 2.5 t/ha GB	13.18	15.49c	3.99b	4.64c
Omank. **x** 150 kg/ha NPK + 1.25 t/ha GB	13.93	16.47abc	4.08ab	4.70c
Omank. **x** 1.25 t/ha GB + 5 t/ha CM	14.53	18.07abc	4.43ab	5.07abc
Omank. **x** No fertilizer (Control)	13.06	15.98c	4.07ab	4.70c
Obatan. **x** 10 t/ha CM	15.54	19.21a	4.67a	5.45a
Obatan. **x** 300 kg/ha NPK 15:15:15	14.09	17.35abc	4.34ab	5.08abc
Obatan. **x** 2.5 t/ha GB	13.97	17.53abc	4.11ab	4.93bc
Obatan. **x** 150 kg/ha NPK + 1.25 t/ha GB	13.89	17.21abc	4.18ab	4.96bc
Obatan. **x** 1.25 t/ha GB + 5 t/ha CM	15.41	18.91ab	4.61ab	5.28ab
Obatan. **x** No fertilizer (Control)	12.89	16.13bc	3.99b	4.71c
HSD (P ≤ 0.05)	**NS**	**2.87**	**0.64**	**0.48**
CV (%)	**7.67**	**5.63**	**5.06**	**3.30**

x – interaction CM – Chicken manure GB – *Gliricidia sepium* biochar

	Cob length	Cob diameter
Variety (V)	= 0.50**	0.09**
Fertilizer rates (Fr.)	= 1.29**	0.25**
Season (S)	= 0.50**	0.09**
S x V	= NS	NS
Fr. x V	= NS	NS
Fr. x S	= NS	NS
S x Fr. x V	= NS	NS

4.4.5 Number of Cobs per Plot

Table 4.7 shows number of cobs per plot as influenced by biochar, chicken manure, and NPK fertilizer. During the minor season (2021), there was a significant ($P \leq 0.05$) difference between Omankwa and Obatanpa in number of cobs per plot. Omankwa recorded the highest (32.50) number of cobs per plot while Obatanpa recorded the least (26.61) number of cobs per plot (Table 4.7). For the fertilizer rates, application of 10 t/ha CM recorded the highest (33.67) number of cobs per plot which was significantly ($P \leq 0.05$) different from the unamended and 150 kg/ha NPK + 1.25 t/ha GB treated plots with the least mean values of 27.50 and 27.67 respectively. There was no significant ($P \geq 0.05$) difference between Omankwa x amended and unamended plots interactions in number of cobs per plot. Similarly, no significant ($P \geq 0.05$) difference occurred between Obatanpa x amended and unamended plots interaction in number of cobs per plot. However, a significant ($P \leq 0.05$) difference occurred between Omankwa x 10 t/ha CM from Obatanpa x 2.5 t/ha GB interaction in number of cobs per plot.

In the major season (2022), biochar, chicken manure, and NPK fertilizer applied either singly or in combination did not significantly influence number of cobs per plot for the two maize varieties (Table 4.7). No significant ($P \geq 0.05$) difference occurred between variety x fertilizer rates interaction for the two maize varieties. There was a significant ($P \leq 0.05$) difference between seasons with number of cobs per plot in the 2022 major season being significantly higher than the numbers obtained in the 2021 minor season (Table 4.7). No significant ($P \geq 0.05$) difference occurred between season x variety x fertilizer rates (Table 4.7).

4.4.6 Hundred seed weight

Table 4.7 shows 100-seed weight as influenced by biochar, chicken manure, and NPK fertilizer. During the 2021 minor season, there was no significant (P≥0.05) difference between the two maize varieties (Omankwa and Obatanpa) in 100-seed weight. For individual effect of fertilizer on 100- seed weight per plot, the highest mean of (27.17 g) recorded by 10 t/ha CM was significantly (P≤0.05) different from other amended plots except 1.25 t/ha GB + 5t /ha CM and the unamended plot with the least mean value of (20.50 g). Omankwa x amended and unamended plots interactions showed no significant (P≥0.05) difference in 100-seed weight. Application of 10 t/ha CM x Obatanpa interaction recorded the highest (28.33g) 100-seed weight which was significantly (P≤0.05) different from Obatanpa x unamended plot interaction with the least mean (20.00 g) (Table 4.7).

In the major season (2022), biochar, chicken manure, and inorganic fertilizer applied either singly or in combination did not significantly influence 100-seed weight for the two maize varieties (Table 4.7). Generally, both maize varieties grown on amended and unamended plots during the 2022 major season had higher 100-seed weight than those obtained during the 2021 minor season. However, there was a significant (P≤0.05) difference between seasons in 100-seed weight. There was no significant (P≥0.05) difference between season x variety x fertilizer rates interactions.

Table 4.7: Number of Cobs per Plot and 100-Seed Weight as affected by biochar, chicken manure and NPK fertilizer during 2021 Minor and 2022 Major Seasons

Treatment	Number of cobs per plot		100-seed weight (g)	
	2021 minor season	2022 major season	2021 minor season	2022 major season
Variety				
Omankwa	32.50a	35.39	22.61	35.61
Obatanpa	26.61b	34.33	23.61	36.61
HSD ($P \leq 0.05$)	**2.11**	**NS**	**NS**	**NS**
Fertilizer rates				
10 t/ha CM	33.67a	36.83	27.17a	37.83
300 kg/ha NPK 15:15:15	29.00ab	34.67	22.67bc	35.83
2.5 t/ha GB	28.00ab	33.50	21.33c	3350
150 kg/ha NPK + 1.25 t/ha GB	27.67b	34.00	22.00bc	36.67
1.25 t/ha GB + 5 t/ha CM	31.50ab	36.12	25.00ab	38.17
No fertilizer (Control)	27.50b	34.00	20.50c	34.67
HSD ($P \leq 0.05$)	**5.47**	**NS**	**3.52**	**NS**
Interaction (V X F)				
Omank. **x** 10 t/ha CM	37.33a	36.67	26.00ab	38.00
Omank. **x** 300 kg/ha NPK 15:15:15	29.33abc	35.67	21.33bc	35.00
Omank. **x** 2.5 t/ha GB	33.33ab	33.33	20.33bc	31.00
Omank. **x** 150 kg/ha NPK + 1.25 t/ha GB	32.33ab	35.00	21.33bc	35.33
Omank. **x** 1.25 t/ha GB + 5 t/ha CM	34.00ab	37.00	25.67abc	38.67
Omank. **x** No fertilizer (Control)	28.67abc	34.67	21.00bc	35.67
Obatan. **x** 10 t/ha CM	30.00abc	37.00	28.33a	37.67
Obatan. **x** 300 kg/ha NPK 15:15:15	28.67abc	33.67	24.00abc	36.67
Obatan. **x** 2.5 t/ha GB	22.67c	33.67	22.33bc	36.00
Obatan. **x** 150 kg/ha NPK + 1.25 t/ha GB	23.00c	33.00	22.67abc	38.00
Obatan. **x** 1.25 t/ha GB + 5 t/ha CM	29.00abc	35.33	24.33abc	37.67
Obatan. **x** No fertilizer (Control)	26.33bc	33.33	20.00c	33.67
HSD ($P \leq 0.05$)	**9.04**	**NS**	**5.82**	**NS**
CV (%)	**10.30**	**6.24**	**8.48**	**7.21**

x – interaction CM – Chicken manure GB – *Gliricidia sepium* biochar

Variety (V)	= 1.38**	NS
Fertilizer rates (Fr.)	= 3.53**	3.92**
Season (S)	= 1.38**	1.53**
S x V	= 2.58**	NS
Fr. x V	= NS	NS
Fr. x S	= NS	NS
S x Fr. x V	= NS	NS

4.4.7 Number of Filled Cobs per Plot

Table 4.8 shows number of filled cobs per plot as influenced by biochar, chicken manure, and NPK fertilizer. During the minor season (2021), there was a significant ($P \leq 0.05$) difference between Omankwa and Obatanpa in number of filled cobs per plot. Omankwa recorded significantly ($P \leq 0.05$) higher (30.11) number of filled cobs per plot than Obatanpa which recorded the least (24.61). For individual effect of fertilizer on number of filled cobs per plot, there was a significant ($P \leq 0.05$) difference between 10 t/ha CM from the unamended plot which recorded the least (24.50) number of filled cobs per plot during the minor season (2021) (Table 4.8). Omankwa x 10 t/ha CM interaction recorded significantly ($P \leq 0.05$) higher (36.33) number of filled cobs per plot than the unamended plot that recorded the least (25) number of filled cobs. There was however no significant ($P \geq 0.05$) difference between Obatanpa x amended and unamended interactions.

In the major season (2022), Omankwa recorded significantly ($P \leq 0.05$) higher (33.00) number of filled cobs per plot than Obatanpa with the least (30.28) mean. There was no significant ($P \geq 0.05$) difference between Omankwa x amended and unamended interactions in number of filled cobs per plot. Obatanpa x amended and unamended plots interactions did not show any significant ($P \geq 0.05$)in number of filled cobs per plot. For fertilizer rates, 10 t/ha CM and 1.25 t/ha GB + 5 t/ha CM recorded significantly ($P \leq 0.05$) higher number of filled cobs per plot than unamended plot with the least mean value of 29.00. Generally, both maize varieties grown on amended and unamended plots during the 2022 major season had higher number of filled cobs per plot than those obtained during the 2021 minor season. However, there was a significant ($P \leq 0.05$) difference between seasons for number of filled cobs per plot. No significant (P≥0.05) difference occurred between season x variety x fertilizer rates interactions (Table 4.8).

4.4.8 Number of Unfilled Cobs per Plot

Table 4.8 shows number of unfilled cobs per plot as influenced by biochar, chicken manure, and NPK fertilizer. During the minor season (2021), there was no significant (P≥0.05) difference between Omankwa and Obatanpa in number of unfilled cobs per plot. For fertilizer rates, unamended plot had a significantly higher (3.33) number of unfilled cobs than 10 t/ha CM that recorded the least (1.17) mean. There was however no significant difference between the other amended plots in number of unfilled cobs per plot (Table 4.8). Omankwa grown on 10 t/ha CM recorded the least (1.00) number of unfilled cobs per plot that differed significantly (P≥0.05) from Omankwa grown on unamended plot with the highest (3.67) number of unfilled cobs per plot. There was no significant (P≥0.05) difference between Obatanpa x amended and unamended plots interaction in number of unfilled cobs per plot.

In the major season (2022), there was a significant (P≤0.05) difference between Omankwa and Obatanpa in number of unfilled cobs per plot. Omankwa recorded the highest (4.06) number of unfilled cobs per plot and Obatanpa recorded the least (2.39) (Table 4.8). There was no significant (P≥0.05) difference between Omankwa x amended and unamended plots interaction in number of unfilled cobs per plot. Obatanpa x unamended plots interaction had significantly (P≤0.05) higher (6.67) number of unfilled cobs per plot than Obatanpa x 1.25 t/ha GB + 5 t/ha CM interaction that recorded the least (2.0) number of unfilled cobs per plot (Table 4.8). A significant (P≤0.05) difference occurred between unamended plots which recorded the highest (5.00) number of unfilled cobs from 1.25 t/ha GB + 5 t/ha CM treated plots (1.67) and 10 t/ha CM (2.1) (Table 4.8).

Generally, both maize varieties grown on amended and unamended plots during the 2022 major season had higher number of unfilled cobs per plot than those obtained during the 2021 minor season. No significant ($P \geq 0.05$) difference occurred between season x variety x fertilizer rates interactions (Table 4.8).

Table 4.8: Number of Filled and Unfilled Cobs per Plot as affected by biochar, chicken manure and NPK fertilizer during 2021 Minor and 2022 Major Seasons

Treatment	Number of filled cobs per plot		Number of unfilled cobs per plot	
	2021 minor season	2022 major season	2021 minor season	2022 major season
Variety				
Omankwa	30.11a	33.00a	2.33	4.06a
Obatanpa	24.61b	30.28b	2.00	2.39b
HSD ($P \leq 0.05$)	**2.38**	**1.94**	**NS**	**1.06**
Fertilizer rates				
10 t/ha CM	32.50a	34.67a	1.17b	2.17b
300 kg/ha NPK 15:15:15	26.50ab	31.83ab	2.17ab	2.83ab
2.5 t/ha GB	25.67b	29.67ab	2.33ab	3.83ab
150 kg/ha NPK + 1.25 t/ha GB	25.00b	30.17ab	2.50ab	3.83ab
1.25 t/ha GB + 5 t/ha CM	30.00ab	34.50a	1.50b	1.67b
No fertilizer (Control)	24.50b	29.00b	3.33a	5.00a
HSD ($P \leq 0.05$)	**6.19**	**5.05**	**1.60**	**2.75**
Interaction (V X F)				
Omank. **x** 10 t/ha CM	36.33a	35.00a	1.00b	1.67b
Omank. **x** 300 kg/ha NPK 15:15:15	27.00abcd	33.33ab	2.00ab	2.33ab
Omank. **x** 2.5 t/ha GB	31.00abc	30.33ab	2.33ab	3.33ab
Omank. **x** 150 kg/ha NPK + 1.25 t/ha GB	29.00abcd	32.67ab	3.33ab	2.33ab
Omank. **x** 1.25 t/ha GB + 5 t/ha CM	32.33ab	35.67a	1.67ab	1.33b
Omank. **x** No fertilizer (Control)	25.00bcd	31.33ab	3.67a	3.33ab
Obatan. **x** 10 t/ha CM	28.67abcd	34.33ab	1.33ab	2.67ab
Obatan. **x** 300 kg/ha NPK 15:15:15	26.00bcd	30.33ab	2.33ab	3.33ab
Obatan. **x** 2.5 t/ha GB	20.33d	29.33ab	2.33ab	4.33ab
Obatan. **x** 150 kg/ha NPK + 1.25 t/ha GB	21.00cd	27.67ab	1.67ab	5.33ab
Obatan. **x** 1.25 t/ha GB + 5 t/ha CM	27.67abcd	33.33ab	1.33ab	2.00b
Obatan. **x** No fertilizer (Control)	24.00bcd	26.67b	3.00ab	6.67a
HSD ($P \leq 0.05$)	**10.21**	**8.33**	**2.64**	**4.55**
CV (%)	**12.57**	**8.87**	**40.91**	**47.53**

x – interaction CM – Chicken manure GB – *Gliricidia sepium* biochar

Variety (V)	= 1.53**	0.61**
Fertilizer rates (Fr.)	= 3.92**	1.55**
Season (S)	= 1.53**	0.61**
S x V	= NS	1.13**
Fr. x V	= NS	NS
Fr. x S	= NS	NS
S x Fr. x V	= NS	NS

4.3.9 Harvest Index

Table 4.9 shows harvest index as influenced by biochar, chicken manure, and NPK fertilizer. During the 2021 minor season, there was a significant ($P \leq 0.05$) difference between Omankwa and Obatanpa in harvest index. Omankwa recorded the highest (0.44) whiles Obatanpa recorded the least (0.31). There was no significant ($P \geq 0.05$) difference between the fertilizer rates applied in harvest index. There was no significant ($P \geq 0.05$) difference between Obatanpa and Omankwa x amended and unamended plots interaction.

In the major season (2022), there was a significant ($P \leq 0.05$) difference between Omankwa and Obatanpa in harvest index. Omankwa recorded significantly higher (0.44) harvest index than Obatanpa which recorded the least (0.38). There was no significant ($P \geq 0.05$) difference between the fertilizer rates applied in harvest index. Similarly, there was no significant ($P \geq 0.05$) difference between variety x fertilizer interaction on harvest index. There was a significant ($P \leq 0.05$) difference between seasons for harvest index. Omankwa x amended and unamended plots interactions recorded higher harvest index than Obatanpa x amended and unamended plots interactions for both seasons. No significant ($P \geq 0.05$) difference occurred between season x variety x fertilizer rates interactions (Table 4.9).

4.4.10 Total Grain Yield

Table 4.9 shows total grain yield as influenced by biochar, chicken manure, and NPK fertilizer. During the minor season (2021), there was a significant ($P \leq 0.05$) difference between Omankwa and Obatanpa in total grain yield. Omankwa recorded significantly higher (2.68 t/ha) total grain yield than Obatanpa which recorded the least (2.23 t/ha) (Table 4.9). The 10 t/ha CM treated plots recorded significantly higher grain yield (3.40 t/ha) than the control

(1.87 t/ha) except 1.25 t/ha GB + 5 t/ha CM. Interactively, there was no significant (P≥0.05) difference between Omankwa grown on amended and unamended plots. Obatanpa x 10 t/ha CM interaction had the highest total grain yield (3.47 t/ha) that was significantly (P≤0.05) different from Obatanpa x control interaction which recorded the least total grain yield (1.50 t/ha).

In the major season (2022), there was no significant (P≥0.05) difference between Omankwa and Obatanpa in total grain yield. The 10 t/ha CM treated plots recorded significantly higher grain yield (6.65 t/ha) than the control (4.50 t/ha) except 1.25 t/ha GB + 5 t/ha CM. There was no significant (P≥0.05) difference between Omankwa x amended and unamended plots interaction in total grain yield. Obatanpa x amended and unamended plots interaction showed a significant (P≤0.05) difference between the treatment means. Obatanpa x 10 t/ha CM interaction had significantly higher (7.47 t/ha) total grain yield than Obatanpa x control interaction (4.03 t/ha) (Table 4.9). There was a significant (P≤0.05) difference between seasons for total grain yield. The total grain yield obtained in the major season (2022) was significantly higher than those obtained in the minor season (2021). No significant (P≥0.05) difference occurred between season x variety x fertilizer rates interactions (Table 4.9).

Table 4.9: Harvest Index and Total Grain Yield as affected by biochar, chicken manure and NPK fertilizer during 2021 Minor and 2022 Major Seasons

Treatment	Harvest index		Total Grain yield (t/ha)	
	2021 minor season	2022 major season	2021 minor season	2022 major season
Variety				
Omankwa	0.44a	0.44a	2.68a	5.14
Obatanpa	0.31b	0.38b	2.23b	5.52
HSD (P ≤ 0.05)	**0.03**	**0.04**	**0.35**	**NS**
Fertilizer rates				
10 t/ha CM	0.36	0.41	3.40a	6.65a
300 kg/ha NPK 15:15:15	0.38	0.44	2.05c	4.80b
2.5 t/ha GB	0.43	0.43	2.47bc	4.65b
150 kg/ha NPK + 1.25 t/ha GB	0.37	0.39	1.92c	4.95b
1.25 t/ha GB + 5 t/ha CM	0.37	0.41	3.02ab	6.45a
No fertilizer (Control)	0.36	0.41	1.87c	4.50b
HSD (P ≤ 0.05)	**NS**	**NS**	**0.90**	**1.44**
Interaction (V X F)				
Omank. **x** 10 t/ha CM	0.39abcd	0.42	3.33a	5.82abc
Omank. **x** 300 kg/ha NPK 15:15:15	0.43ab	0.45	2.00ab	4.91bc
Omank. **x** 2.5 t/ha GB	0.50a	0.49	2.83ab	4.09c
Omank. **x** 150 kg/ha NPK + 1.25 t/ha GB	0.45ab	0.41	2.13ab	4.98bc
Omank. **x** 1.25 t/ha GB + 5 t/ha CM	0.41abc	0.43	3.46a	6.09abc
Omank. **x** No fertilizer (Control)	0.44ab	0.46	2.33ab	4.96bc
Obatan. **x** 10 t/ha CM	0.32bcd	0.39	3.47a	7.47a
Obatan. **x** 300 kg/ha NPK 15:15:15	0.32bcd	0.43	2.11ab	4.70bc
Obatan. **x** 2.5 t/ha GB	0.36abcd	0.36	2.10ab	5.20abc
Obatan. **x** 150 kg/ha NPK + 1.25 t/ha GB	0.28cd	0.37	1.62b	4.92bc
Obatan. **x** 1.25 t/ha GB + 5 t/ha CM	0.33bcd	0.38	2.59ab	6.80ab
Obatan. **x** No fertilizer (Control)	0.27d	0.36	1.50b	4.03c
HSD (P ≤ 0.05)	**0.14**	**NS**	**1.48**	**2.38**
CV (%)	**12.66**	**14.88**	**20.36**	**15.03**

x – interaction CM – Chicken manure GB – *Gliricidia sepium* biochar

	Harvest index	Total Grain yield
Variety (V)	= 0.03**	NS
Fertilizer rates (Fr.)	= NS	1.00**
Season (S)	= 0.03**	0.39**
S x V	= 0.05**	0.73**
Fr. x V	= NS	NS
Fr. x S	= NS	NS
S x Fr. x V	= NS	NS

4.5 Partial budget analysis for Omankwa and Obatanpa maize varieties

Table 4.10 shows the information used for the partial budget analysis to determine the relative economic benefit of the applied treatments on the two maize varieties (Omankwa and Obatanpa) in 2021 minor and 2022 major cropping seasons. The farm gate price for a bag of maize (100 kg) and the cost of farm services were taken at the Asante Mampong market in the Ashanti Region of Ghana. The cost of biochar production was determined through the labour cost involved. Due to the significant depreciation over the years and their negligible values, certain capital expenses such as land and management fees, seed cost, seed planting cost, operational capital interests, machinery and equipment depreciation, and other indirect costs were excluded from consideration.

Table 4.10: Information used for the partial budget analysis

Variable/Quantity	Cost
1. Farm gate price of maize (t/ha)	GH¢350.00
2. Fertilizer cost	
• 5 kg of 15-15-15 NPK	GH¢18.00
• Labour cost for application	GH¢9.00
3. Chicken manure (150 kg)	GH¢45.00
• Labour cost for application	GH¢9.00
4. Biochar production (47 kg)	GH¢470.00
• Labour cost for application	GH¢12.00
5. Transportation cost	
• 5 kg of inorganic fertilizer	GH¢5.00
• 150 kg chicken manure	GH¢10.00
• 47 kg Biochar	GH¢12.00

4.5.1 Partial budget analysis of Omankwa and Obatanpa maize varieties as affected by biochar, chicken manure, and NPK fertilizer during 2021 minor and 2022 major growing seasons

During the 2021 minor and 2022 major growing seasons, Omankwa and Obatanpa x 300 kg/ha NPK 15:15:15 interaction attracted the lowest total variable cost while Omankwa and Obatanpa x 2.5 t/ha GB interaction recorded the highest total variable cost (Tables 4.11, 4.12, 4.13 and 4.14). Omankwa and Obatanpa x 300 kg/ha NPK 15:15:15 interaction during the 2021 minor and 2022 major growing seasons had higher marginal rate of returns than the other amended and the control plots (Tables 4.11, 4.12, 4.13 and 4.14). In the 2021 minor season, Omankwa and Obatanpa x 300 kg/ha NPK 15:15:15 interaction showed that for every GH¢ 1.0 investment for production, you get GH¢ 58.04 as profit for Omankwa and GH¢ 61.32 for Obatanpa respectively (Tables 4.11 and 4.12). In the case of the 2022 major season, for every GH¢ 1.0 investment for production under 300 kg/ha NPK 15:15:15 you get GH¢ 143.99 as profit for Omankwa and GH¢ 137.75 for Obatanpa respectively (Tables 4.13 and 4.14).

Table 4.11: Partial budget analysis for Omankwa variety of maize as affected by biochar, chicken manure, and NPK fertilizer during 2021 minor season

	No fertilizer (control)	**10t/ha CM**	**300 kg/ha NPK 15:15:15**	**2.5 t/ha GB**	**150 kg/ha NPK 15:15:15 + 1.25 t/ha GB**	**1.25 t/ha GB + 5 t/ha CM**
Gross benefits						
Yield (t/ha)	2.32	3.33	2	2.83	2.13	3.46
Adjusted yield (90%) (t ha-^{1})	2.09	3.00	1.80	2.55	1.92	3.20
Total Gross Benefit (TGB)	731.5	1050	630	892.5	672	1120
Variable Cost (GH₵)						
Fertilizer Cost						
• CM	0	15.00	0	0	0	7.50
• NPK	0	0	6.01	0	3.00	0
• GB	0	0	0	117.5	58.75	58.75
Application Cost (GH₵)						
• CM	0	3.00	0	0	0	1.50
• NPK	0	0	3.00	0	1.50	0
• GB	0	0	0	3.00	1.50	1.50
Transportation Cost (GH₵)						
• CM	0	3.33	0	0	0	1.67
• NPK	0	0	1.67	0	0.83	0
• GB	0	0	0	3.00	1.50	1.50
Total Variable Cost (TVC)	0	21.33	10.67	123.5	67.08	72.42
Net Benefit (TGB-TVC)	731.5	1028.67	619.33	769.0	604.92	1047.58
Marginal Rate of Return (MRR) = ΔNB/ΔTVC × 100		48.23	58.04	6.23	9.02	14.47

Table 4.12: Partial budget analysis for Obatanpa variety of maize as affected by biochar, chicken manure, and NPK fertilizer during 2021 minor season

	No fertilizer (control)	**10t/ha CM**	**300 kg/ha NPK 15:15:15**	**2.5 t/ha GB**	**150 kg/ha NPK 15:15:15 + 1.25 t/ha GB**	**1.25 t/ha GB + 5 t/ha CM**
Gross benefits						
Yield (t/ha)	1.5	3.47	2.11	2.1	1.62	2.59
Adjusted yield (90%) (t ha-^{1})	1.35	3.12	1.90	1.89	1.46	2.33
Total Gross Benefit (TGB)	472.5	1092	665	661.5	511	815.5
Variable Cost (GH₵)						
Fertilizer Cost						
• CM	0	15.00	0	0	0	7.50
• NPK	0	0	6.01	0	3.00	0
• GB	0	0	0	117.5	58.75	58.75
Application Cost (GH₵)						
• CM	0	3.00	0	0	0	1.50
• NPK	0	0	3.00	0	1.50	0
• GB	0	0	0	3.00	1.50	1.50
Transportation Cost (GH₵)						
• CM	0	3.33	0	0	0	1.67
• NPK	0	0	1.67	0	0.83	0
• GB	0	0	0	3.00	1.50	1.50
Total Variable Cost (TVC)	0	21.33	10.67	123.5	67.08	72.42
Net Benefit (TGB-TVC)	472.5	1070.67	654.33	538.0	443.92	743.08
Marginal Rate of Return (MRR) = ΔNB/ΔTVC × 100		50.20	61.32	4.36	6.62	10.26

Table 4.13: Partial budget analysis for Omankwa variety of maize as affected by biochar, chicken manure, and NPK fertilizer during 2022 major season

	No fertilizer (control)	**10t/ha CM**	**300 kg/ha NPK 15:15:15**	**2.5 t/ha GB**	**150 kg/ha NPK 15:15:15 + 1.25 t/ha GB**	**1.25 t/ha GB + 5 t/ha CM**
Gross benefits						
Yield (t/ha)	4.95	5.83	4.91	4.09	4.98	6.09
Adjusted yield (90%) (t ha-^{1})	4.46	5.25	4.42	3.68	4.48	5.48
Total Gross Benefit (TGB)	1561	1837.5	1547	1288	1568	1918
Variable Cost (GH₵)						
Fertilizer Cost						
• CM	0	15.00	0	0	0	7.50
• NPK	0	0	6.01	0	3.00	0
• GB	0	0	0	117.5	58.75	58.75
Application Cost (GH₵)						
• CM	0	3.00	0	0	0	1.50
• NPK	0	0	3.00	0	1.50	0
• GB	0	0	0	3.00	1.50	1.50
Transportation Cost (GH₵)						
• CM	0	3.33	0	0	0	1.67
• NPK	0	0	1.67	0	0.83	0
• GB	0	0	0	3.00	1.50	1.50
Total Variable Cost (TVC)	0	21.33	10.67	123.5	67.08	72.42
Net Benefit (TGB-TVC)	1561	1816.17	1536.33	1164.5	1500.92	1845.58
Marginal Rate of Return (MRR) = ΔNB/ΔTVC × 100		85.15	143.99	9.43	22.38	25.48

Table 4.14: Partial budget analysis for Obatanpa variety of maize as affected by biochar, chicken manure, and NPK fertilizer during 2022 major seasons

	No fertilizer (control)	**10t/ha CM**	**300 kg/ha NPK 15:15:15**	**2.5 t/ha GB**	**150 kg/ha NPK 15:15:15 + 1.25 t/ha GB**	**1.25 t/ha GB + 5 t/ha CM**
Gross benefits						
Yield (t/ha)	4.03	7.47	4.7	5.2	4.92	6.8
Adjusted yield (90%) (t ha-^{1})	3.63	6.72	4.23	4.68	4.43	6.12
Total Gross Benefit (TGB)	1270.5	2352	1480.5	1638	1550.5	2142
Variable Cost (GH₵)						
Fertilizer Cost						
• CM	0	15.00	0	0	0	7.50
• NPK	0	0	6.01	0	3.00	0
• GB	0	0	0	117.5	58.75	58.75
Application Cost (GH₵)						
• CM	0	3.00	0	0	0	1.50
• NPK	0	0	3.00	0	1.50	0
• GB	0	0	0	3.00	1.50	1.50
Transportation Cost (GH₵)						
• CM	0	3.33	0	0	0	1.67
• NPK	0	0	1.67	0	0.83	0
• GB	0	0	0	3.00	1.50	1.50
Total Variable Cost (TVC)	0	21.33	10.67	123.5	67.08	72.42
Net Benefit (TGB-TVC)	1270.5	2330.67	1469.83	1514.5	1483.42	2069.58
Marginal Rate of Return (MRR) = ΔNB/ΔTVC × 100		109.27	137.75	12.26	22.11	28.58

CHAPTER FIVE

5.0 DISCUSSION

5.1 Effect of amendment on soil chemical properties.

The results of the study showed that soil fertility was improved by the application of chicken manure and the combined application of chicken manure and biochar. This indicated that manure treated soils might have produced the highest amount of total N, available P, exchangeable bases (K, Ca, Mg and Na), and organic matter which were essential to improve the soil fertility as compared to other amended plots and the control. This corroborates with Ravi *et al*. (2012) that the addition of chicken manure increased soil organic matter which increased total N, and available P and exchangeable bases such as Mg, K, Ca, and Na. In a study to determine the effects of chicken manure on soil chemical properties and nutrient bioavailability to soybean, Soremi *et al.* (2017) reported significantly greater soil organic matter, organic carbon, exchangeable bases, and effective cation exchange capacity in soils treated with organic manure.

In comparison to NPK-treated soils, Atijegbe *et al.* (2014) reported that the addition of 10 t/ha CM enhanced soil organic matter, as well as N, P, K, Ca, and Mg concentrations in soil and also increased soil pH. Van Zwieten *et al.* (2010) conducted a thorough study on biochar and found that applying paper-mill biochar at a rate of 10 t/ha raised pH, CEC, exchangeable Ca, and total K while decreasing Al availability in a Ferrosol soil while increasing C and exchangeable K in a Calcarosol soil. Agbede & Oyewumi (2022) found that the combined application of poultry manure and biochar improved soil chemical properties (N, P, K, Mg, Ca, OC and soil pH) as compared to the sole application of biochar and poultry manure and the unamended plot.

5.2 Effect of biochar, chicken manure and NPK fertilizer on phenology of two maize varieties

The effect of biochar, chicken manure, and inorganic fertilizer on Omankwa and Obatanpa maize varieties showed that 50% emergence of seedlings took between 4 and 5 days to occur for the minor (2021) and major (2022) growing seasons respectively. The least number of days to 50% seedling emergence recorded by Omankwa in the 2022 major season could be due to differences in the varieties and their response to soil nutrients and soil moisture. The least number of days to 50% seedling emergence recorded by 10 t/ha CM and 1.25 t/ha GB + 5 t/ha CM might probably be due to the water retention capacity of the chicken manure treated plots that provided optimum temperature and moisture for seedling emergence.

Chicken manure enhances soil water holding capacity, improves soil structure, soil aeration, water permeability, and contains metal-organic matter compounds that help make nutrients available to crops (Yolanda *et al.*, 2014). According to Indira & Annadurai (2016), poultry manure increases soil microbial activity, functions as a pH buffer, and helps to improve both the physical (texture, structure and bulk density) and chemical properties of soil for effective seedling growth. The insignificant differences between the interactive effects of variety and fertilizer in number of days to 50% seedling emergence in both growing seasons may be due to assumptions that, at the earliest stages of growth, seedlings obtain nutrients from stored nutrients in seeds acting as sinks.

Varieties showed no significant differences in percentage crop establishment in both growing seasons. However, the highest percentage crop establishment produced by 10 t/ha CM and 1.25 t/ha GB + 5 t/ha CM across the two growing seasons might be due to higher amount of macronutrients (N, P, K) and micronutrients available in the chicken manure and biochar in the soils which enhanced effective growth and development and hence higher number of established plants. Erkalo *et al.* (2023) found that differences in macro and micronutrients in organic manure increased vegetative growth through the synthesis of protein. Omankwa x 1.25 t/ha GB + 5 t/ha CM or 10 t/ha CM interactions resulted in a higher percentage crop establishment. This might be due to varietal differences and their response to nutrients, higher amount of macro and micronutrients, increased fertility, and improved SOC contents while reducing the leaching of nutrients, especially N, P and K as a result of the incorporation of biochar and chicken manure. This improves soil properties for root growth and nutrient absorption (Olmo *et al.,* 2016; Cheng *et al.*, 2018). This is in accordance with the findings by Wisnubroto *et al.* (2017) in red chili that biochar and chicken manure amendment gave rapid vigorous crop growth.

The delay in tasseling and silking in Obatanpa as compared to Omankwa in both growing seasons could be due to the differences in the genetic makeup of the varieties and their response to available soil nutrients. This agrees with Faisal (2015) that varieties had a significant impact on days to 50% tasseling and silking. The 10 t/ha CM and 1.25 t/ha GB +5 t/ha CM and their interactions with Obatanpa and Omankwa produced the least number of days to 50% tasseling and silking in both growing seasons. This could be due to the higher amount of organic matter available in the chicken manure and biochar-treated soils, which enhanced the water-holding capacity of the soil, promotes aeration and drainage, and decreases soil loss by erosion. Again, it could be due to the higher levels of macro and micronutrients available in the chicken manure and the ability of biochar to bind the soil particles together thereby making soil nutrients readily available for plants to absorb and utilize leading to earlier tasseling and silking. Kroma *et al.* (2016) reported that organic manure promotes water holding capacity of the soil, increases soil pH and porosity, lowers temperature, conserves soil moisture, and prevents nutrient leaching that ensures early reproductive growth and development.

This corroborates with Gurmu & Mintesnot (2020) who observed greater number of days to tasseling and silking in unamended soils as compared to amended soils. Previous studies have demonstrated the effectiveness of biochar in increasing soil water holding capacity (WHC), enhancing soil pH and reducing nutrient leaching (N, P, Mg, and Si) (Laird *et al.,* 2010; Sorrenti & Toselli, 2016) and that plants have better access to nutrients e.g. N for effective growth. Biochar application in combination with organic manure increases soil C storage and minimizes nitrate and ammonium leaching, increasing nutrient availability to plants and improving plant development (Wang *et al.,* 2017; Kavitha *et al.,* 2018). The higher number of days to tasseling and silking in unamended plots might be attributed to the inability of the soil to supply essential plant nutrients for effective growth. This agrees with Olatunji *et al.* (2020) that unamended soils supplied little or no nutrient that are essentially needed for reproductive growth and development.

5.3 Effect of biochar, chicken manure and NPK fertilizer on vegetative growth of two maize varieties

Obatanpa produced significantly taller plants, wider stem diameter, higher number of leaves per plant, and heavier shoot and root fresh weight than Omankwa in both cropping seasons. However, Omankwa produced higher leaf chlorophyll content than Obatanpa in both cropping seasons. This is an indication of differences in the genetic composition of the two varieties and their response to growth factors such as soil moisture and nutrients. 10 t/ha CM significantly improved vegetative growth (e.g. taller plant and higher number of leaves per plant) than the other amended plots and the control. This could be due to the higher supply of essential plant nutrients and the improvement of the soil physicochemical properties by the chicken manure applied. Animal manure, according to Pampuro *et al.* (2018), provides a wide spectrum of plant nutrients as well as organic matter for improving soil's physical and chemical properties. e.g. water holding capacity and pH buffer.

Plant height and number of leaves per plant of both maize varieties (Omankwa and Obatanpa) grown on 10 t/ha CM or 1.25 t/ha GB + 5 t/ha CM were significantly higher than the control plot and other amendments in both cropping seasons. This might be due to the supply of macronutrients, especially N and other micronutrients from chicken manure and biochar application. This agrees with Alubiagba *et al.* (2021), who identified chicken manure to have special characteristics of faster mineralization than other organic manures and rapid release of macro and micro nutrients for plant uptake and utilization. Similarly, according to Asfaw (2022), effective vegetative growth and hence higher plant height was due to nitrogen in the chicken manure, which increased the number of nodes and the length of the internodes and consequently the plant height. This is in agreement with Krishna & Singh (2022) that organic manure supplies essential nutrient elements to promote vigorous growth and physiological activities in the plant system. Aziz *et al.* (2020) reported a higher number of leaves of forage sorghum due to the application of chicken manure which supplied essential plant nutrients and improved soil physicochemical properties. Studies have shown that applying poultry manure can increase soil fertility in terms of K and P without increasing soil salinity in sandy soil and continuously lowering soil temperature by 2 - 2.3 ^{o}C for optimum plant growth and hence higher number of leaves (Wali *et al.,* 2020). Biochar enhances soil physicochemical properties which influenced the growth and yield attributes and enhanced groundnut yield by 29% over the control (Pandian *et al.,* 2016).

The wider stem diameter, higher leaf chlorophyll content, and higher shoot and root fresh weight produced by both maize varieties (Obatanpa and Omankwa) grown on 10 t/ha CM and 1.25 t/ha GB + 5 t/ha CM than unamended plots might be due to the adequate amount of nutrients supplied by chicken manure and biochar application. The consistently poor performance of control plots (non-fertilized) and those with other amendments revealed that when nutrients are available in adequate amounts, plant tends to grow at their optimum potential and this might have been responsible for the observed increase in stem diameter of both varieties grown on chicken manure and biochar treated soils (Eleduma *et al.,* 2020). The higher humic substance in organic manure helped in the development of plant roots and this in turn helped plants in drawing water as well as other nutrients, especially nitrogen which is a vital component of chlorophyll from the soil. Pangaribuan *et al*. (2020) asserted that the addition of organic manure improves the plant rhizosphere, making soil aeration better for the absorption of N nutrients which is recognized as an integral constituent in chlorophyll formation that is indicated by increased green leaf colour. The increase in shoot and root biomass yield has been reported by Setyowati (2022) that application of chicken manure enhances nutrient absorption and improves plant growth; as a result, an increase in plant fresh weight which directly translates into higher dry weight. Chicken manure enhanced fresh and dry weight of shoot and root because it decomposed more quickly, allowing it to release nutrients for the roots to absorb hence the increased shoot and root biomass (Nariratih *et al*., 2013).

Similarly, the increase in all vegetative growth in 1.25 t/ha GB + 5 t/ha CM treated plots could be due to the presence of biochar in addition to chicken manure-treated soils that binds the soil particles together thereby preventing the leaching of vital nutrients available in the soil. Biochar application in combination with organic manure, according to Wang *et al.* (2017), increases soil C storage and minimizes nitrate and ammonium leaching, as well as increases nutrient availability to plants and improves plant development (Kavitha *et al.,* 2018).

5.4 Effect of biochar, chicken manure and NPK fertilizer on yield and yield components of maize

Omankwa produced significantly higher number of plants harvested, number of cobs per plant and per plot, higher number of filled cobs per plot and harvest index than Obatanpa in both cropping seasons. However, Obatanpa produced longer cob length, wider cob diameter and higher 100-seed weight per plot, and then the least number of unfilled cobs per plot than Omankwa in both cropping seasons. During the 2021 minor cropping season, Omankwa produced higher yield than Obatanpa; vice versa in the 2022 major season. This significant difference between the two maize varieties (Omankwa and Obatanpa) might be due to differences in the genetic composition of the two varieties and their response to soil moisture and nutrients as well as differences in climatic conditions in terms of light, rainfall, and temperature.

Application of 10 t/ha CM and 1.25 t/ha GB + 5 t/ha CM significantly enhanced yield and yield components than other amended and control plots in both cropping seasons. This could be attributed to the higher amount of macronutrients available in the chicken manure and biochar-treated soils that ensured the continuous supply and easy release of nutrients to the plants for effective growth and subsequent high yield. Accessibility of nutrients in the soil as a result of manure and biochar might have improved the supply of N, P, K, Ca, and Mg, thereby improving the vegetative growth and development that translated into higher yield (Olatunji *et al.*, 2020). The better yield recorded by 10 t/ha CM and 1.25 t/ha GB +5 t/ha CM could be linked to the increase in macro and micronutrient levels in chicken manure and biochar-treated soils which enhanced better uptake of all the nutrients and increased translocation of photosynthetic materials from source to sink (Massaquoi *et al.* 2021). This corroborates with Adekiya *et al.* (2020) that organic manure supplies essential macronutrients that increased the photosynthetic activity of plants which finally moved to the sink and produce higher yields. The increased yield and yield attributes with chicken manure might be because of the rapid availability and utilization of nitrogen for various internal plant processes for carbohydrate production which is later hydrolyzed into reproductive sugars which ultimately helped in increasing yield. The carbohydrate content due to the application of poultry manure and biochar might be attributed to a balanced C: N ratio and increased activity of plant metabolism (Dayo-Olagbende *et al.*, 2018). The addition of biochar with organic soil amendment is critical for optimum soil fertility and nutrient usage efficiency; consequently, it is critical to locate a fast-acting nutrient source for biochar (Adekiya *et al.*, 2020). Adekiya *et al.* (2020) further asserted that combining 15 t/ha BC with 15 t/ha poultry manure (BC+PM) increased soil physical and chemical characteristics, growth, and ginger yield when compared to their sole application and the unamended plot. The physical and chemical characteristics of biochar have a crucial role in determining the characteristics of soil and thereby boosting soil fertility, evidence suggests that biochar's porous structure enables more water retention, which increases crop yield, the most important aspect of water holding capacity (Asadi *et al.*, 2021).

Obatanpa and Omankwa x 10 t/ha CM and 1.25 t/ha GB + 5 t/ha CM interactions produced significantly higher yield and yield components than Obatanpa and Omankwa x control interaction in both seasons except for harvest index where Omankwa x 2.5 t/ha GB recorded the highest in both seasons. This might be due to the higher levels of macronutrients (N, P, K) and the ability of the biochar to prevent leaching of the essential macro nutrients through binding of soil particles together for optimum absorption that translated into higher yield. According to Essilfie *et al.* (2017) application of high rate of chicken manure to both maize varieties (Omankwa and Obatanpa) improved the nutrient status of the soil which promoted broader grain size and heightened meristematic activities that favoured the enlargement of cob and increase in cob length which translated into higher yield. This might be due to the ability of organic manure to enhance the physicochemical parameters of the soil, through addition of nutrients to the soil and also eased the release of nutrients for uptake by maize plants (Umoh *et al.*, 2022). Again, availability of macro nutrients in manure increased the photosynthetic activity of plants which finally moved to the sink and produce highest yield components (Adekiya *et al.*, 2020). This corroborates with Afriyie-Debrah *et al.* (2019) that yield components (ear weight, ear length, ear diameter and 100-seed weight) were significantly increased with the application of chicken manure which resulted in an overall increase in grain yield per hectare. This finding is in accordance with Ansa (2022) that application of poultry manure at a rate of 40 g per plant recorded the thickest cob diameter and longest cob length.

The combined application of biochar with chicken manure had the potential to prevent the leaching of the essential macronutrients by binding the soil particles together for optimum absorption of water and macro and micro nutrients which might have been the reason for higher yield. This is in accordance with the findings by Wisnubroto *et al.* (2017) with red chili who attributed the rapid vigorous crop growth and yield to biochar residue mixed with farmyard manure (FYM). Biochar application in combination with organic manure, according to Wang *et al.* (2017), increases soil C storage and minimizes nitrate and ammonium leaching, as well as increasing nutrient availability to plants and improves plant development and agricultural yields (Kavitha *et al.,* 2018). Biochar enhances crop productivity of many cereal crops, which include maize; however, Peiris & Weerakkody (2015) discovered that yield and yield components increased significantly in maize plants that received biochar.

5.5 Effect of cropping season on yield of maize

Differences were observed in the yield and yield components except for number of plants harvested and number of cobs per plant of maize (Omankwa and Obatanpa) between the two cropping seasons. Yields were better in 2022 major season than in 2021 minor season. Since the crop was raised under identical levels of management, resources and cultivation practices, the variation in growth and yield between the two cropping seasons could be a result of differences in climatic conditions that affected plant growth, which in turn, might have influenced the yield. This corroborates with Tesfaye *et al.* (2018) who observed that weather condition is a principal input parameter that could bring about year-to-year variation in the productivity of crops despite the consistency of other input parameters and practices of crop husbandry. The high rainfall and low temperature experienced during the 2022 cropping season might have contributed to the higher yield. Again, the low rainfall and high temperature during the 2021 cropping season might have contributed to the lower grain yield.

5.6 Partial budget analysis of maize as affected by biochar, chicken manure, and NPK fertilizer

Economic analysis showed varied effects on both variable costs and revenues due to the application of different soil amendments on maize production in both cropping seasons. From this study, the application of 300 kg/ha NPK proved to be more cost-effective followed by 10 t/ha CM for the production of both maize varieties in both cropping seasons than the other amendments and the control plots. The marginal rate of return differences observed could be attributed to the variation in nutrient constituents of the individual amendment. Again, the progressively high performance of 300 kg/ha NPK during both seasons might be attributed to the higher nitrogen levels in the NPK fertilizer. The results obtained were similar to the findings of Hillary *et al.* (2018) who observed that NPK fertilizer recorded the highest benefit-to-cost ratio value due to relatively low production cost and high yields that translated to higher revenues of maize yield.

CHAPTER SIX

6.0 CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

Based on the results of the field studies across both cropping seasons the following conclusions were drawn:

Objective 1:

- It was observed that the sole application of chicken manure and combined application of chicken manure and biochar increased soil nutrients levels such as total N, available P, exchangeable bases (K, Ca, Mg, Na) as well as increasing soil pH. It also increased the organic matter content of the soil.

Objective 2:

The application of *Gliricidia sepium* biochar, chicken manure, and NPK 15:15:15 fertilizer as mineral supplements either alone or in combination influenced the phenology and vegetative growth of the two varieties of maize.

- The application of 1.25 t/ha GB + 5 t/ha CM to the two maize varieties produced the least number of days to emergence across both cropping seasons and had higher number of established plants in the 2021 minor season.
- The application of 10 t/ha CM to the two maize varieties tasseled and silked earliest and was significantly different from the control in both 2021 minor and 2022 major cropping seasons and also had higher number of established plants in the 2022 major season.

- Omankwa tasseled and silked 5-7 days earlier than Obatanpa in both 2021 minor and 2022 major cropping seasons, respectively.
- There was no significant difference between the application of 10 t/ha CM and 1.25 t/ha GB + 5 t/ha CM to the two maize varieties in days to 50% tasseling and silking during 2022 major cropping season.
- Omankwa and Obatanpa grown on 10 t/ha CM and 1.25 t/ha GB + 5 t/ha CM produced the least number of days to seedling emergence across both seasons.
- Omankwa grown on 1.25 t/ha GB + 5 t/ha CM and 10 t/ha CM produced higher percentage crop establishment in the minor and major seasons respectively.
- Obatanpa, 10 t/ha CM and 1.25 t/ha GB + 5 t/ha CM produced higher shoot and root biomass, number of leaves per plant, wider stem diameter, and taller plants than Omankwa and other amended plots across both seasons.
- Omankwa grown on 10 t/ha CM gave the highest leaf chlorophyll content than other amended and the control plots as compared to Obatanpa grown on the same treatments.

Objective 3:

- Omankwa and Obatanpa grown on 150 kg/ha NPK + 1.25 t/ha GB and 10 t/ha CM gave the highest number of harvested plants in the 2021 minor and 2022 major cropping seasons respectively.
- Omankwa and Obatanpa grown on 10 t/ha CM and 1.25 t/ha GB + 5 t/ha CM gave the highest number of cobs per plant in both seasons.
- Omankwa and Obatanpa grown on 10 t/ha CM gave the highest number of cobs per plot in the 2021 minor and 2022 major growing seasons respectively. However,

Omankwa grown on 10 t/ha CM gave the highest during the 2021 minor growing season.

- Obatanpa produced wider cob diameter (5.07 cm) than Omankwa (4.79 cm) during 2022 major cropping season.
- Omankwa produced significantly higher grain yield (2.68 t/ha) than Obatanpa (2.23 t/ha) during 2021 minor cropping season.
- Application of 10 t/ha CM and 1.25 t/ha GB + 5 t/ha CM on maize did not differ significantly in cob diameter and grain yield, however differed significantly from the unamended plot in both cropping seasons.
- Obatanpa grown on 10 t/ha CM gave the longest cob length, widest cob diameter and highest grain yield in both growing seasons. However, Omankwa grown on 1.25 t/ha GB + 5 t/ha CM gave the highest 100-seed weight.
- Omankwa grown on 2.5 t/ha GB gave the highest harvest index in both seasons.
- Generally, Omankwa grown on 10 t/ha CM produced the highest number of filled and least number of unfilled cobs in both seasons.

Objective 4:

- Omankwa and Obatanpa grown on 300 kg/ha NPK 15-15-15 dominated in terms of the marginal rate of return than the other amended and the control plots in both growing seasons. However, Omankwa grown on 300 kg/ha NPK 15-15-15 produced the highest marginal rate of return (GH¢143.99) than Obatanpa grown on the same treatment plot in the 2022 major season.

6.2 Recommendation

Based on the findings of the experiment, it is recommended that:

- Maize farmers are encouraged to use sole chicken manure at a rate of 10 t/ha or 1.25 t/ha GB + 5 t/ha CM to improve soil fertility and productivity.
- Maize farmers are encouraged to grow Omankwa variety and apply 10 t/ha CM or 1.25 t/ha GB + 5 t/ha CM for early tasseling and silking and subsequently mature early.
- Obatanpa should be grown on 10 t/ha CM or 1.25 t/ha GB + 5 t/ha CM for higher vegetative biomass that can serve as mulch, fuel wood or ruminant feed in other agro-ecological zones.
- For wider cob diameter and higher cob length and higher grain yield, maize farmers are to grow Obatanpa and Omankwa, respectively using either 10 t/ha CM and/or 1.25 t/ha GB + 5 t/ha CM.
- For higher profitability, farmers should apply 300 kg/ha NPK 15-15-15 on their fields although did not produce higher yield as compared to other amended plots.
- NPK fertilizer of different grade containing higher amount of nitrogen (such as 30-10-10 and 40-10-10) should be used in future studies.
- The work should be repeated in other agro-ecological zones of Ghana to confirm the results.

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LIST OF APPENDICES

Appendix 1: Guide to interpretation of soil analytical data in Ghana

Nutrient	Rank/Grade
Phosphorus, P (ppm), (Bray 1)	
< 10	Low
10 – 20	Moderate
> 20	High
Potassium, K (pmm)	
< 50	Low
50 – 100	Moderate
> 100	High
Calcium, Ca (ppm)/Meg = 0.25 Ca	
< 5.0	Low
5.0 – 10.0	Moderate
> 10.0	High
ECEC (cmol (+)/kg)	
< 10	Low
10 - 20	Moderate
> 20	High
Soil pH (Distilled Water Method)	
< 5.0	Very Acidic
5.1 – 5.5	Acidic
5.6 – 6.0	Moderately Acidic
6.0 – 6.5	Slightly Acidic
6.5 – 7.0	Neutral
7.0 – 7.5	Slightly Alkaline
7.6 – 8.5	Alkaline
> 8.5	Very Alkaline
Organic Matter (%)	
< 1.5	Low
1.6 – 3.0	Moderate
3.0	High
Nitrogen (%)	
< 0.1	Low
0.1 – 0.2	Moderate
> 0.2	High
Exchangeable Potassium (cmol (+)/kg)	
< 0.2	Low
0.2 – 0.4	Moderate
> 0.4	High

Source : (SRI, 2007)

Appendix 2: Climatic Data for 2021 Minor Rainy Season at the Experimental Site for Experiment One (1)

Month	Total Rainfall (mm)	Relative Humidity (%)	Mean Temperature (^{O}C)	
			Max	Min
August, 2021	169.5	77	29.7	22.7
September	225.1	77	30.3	23.2
October	208.7	72	32.1	22.3
November	73.4	68	33.1	23.4
December	0.0	58	34.3	23.7
Total	676.7			

(Ghana Meteorological Agency– Mampong Ashanti, 2021)

Appendix 3: Climatic Data for 2022 Major Rainy Season at the Experimental Site for Experiment Two (2)

Month	Total Rainfall (mm)	Relative Humidity (%)	Mean Temperature (^{O}C)	
			Max	Min
March, 2022	109.2	67	34	23.9
April	79.6	66	33.1	23.5
May	147.8	71	32.7	23.8
June	149.0	74	31	23.3
July	203.6	74	30	22.7
Total	694.6			

(Ghana Meteorological Agency– Mampong Ashanti, 2022)